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The SCIENTIFIC MONTHLY

OL. 82 NO. 2

FEBRUARY 1956

Experimental model of Bell's new high-frequency transistor. It has a cut-off frequency of at least 500 mc and can be used to amplify 2500 independent voices simultaneously.

THE TRANSISTOR

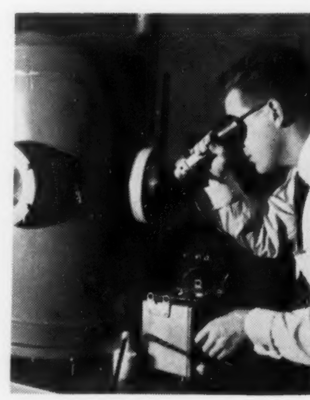
that smashed a frequency barrier

A new transistor invented at Bell Telephone Laboratories can provide broadband, high-frequency amplification never before possible with transistors. The big leap in frequency is made possible by a diffusion process that earlier enabled Laboratories scientists to create the Bell Solar Battery.

This transistor is a three-layer semiconductor "sandwich." High-frequency operation is obtained by making the central layer exceedingly thin. This had previously been difficult to do economically.

The new diffusion process, however, easily produces microscopic layers of controllable thickness. Thus it opens the way to the broad application of high-frequency transistors for use in telephony, FM, TV, guided missiles, electronic brains and computers.

The new transistor shows once again how Bell Laboratories creates significant advances and then develops them into ever more useful tools for telephony and the nation.



Scientist checks temperature as arsenic vapor diffuses into germanium, creating 4/100,000-in. layer.

BELL TELEPHONE LABORATORIES

Improving America's telephone service provides careers for creative men in scientific and technical fields

THE SCIENTIFIC MONTHLY

VOL. 82 — FEBRUARY 1956 — NO. 2

Cover: Hungry Horse Dam, Montana

[Courtesy U.S. Department of the Interior, Bureau of Reclamation, see page 74]

THE SCIENTIFIC MONTHLY, established in 1872 as *The Popular Science Monthly*, has been an official publication of the American Association for the Advancement of Science since 1915. It is published for the Association at Business Press, Inc., Lancaster, Pa.

Entered at the Lancaster, Pa., Post Office as second class matter under the act of March 3, 1879.

All correspondence should be addressed to THE SCIENTIFIC MONTHLY, 1515 Massachusetts Ave., N.W., Washington 5, D. C. Manuscripts should be typed with double spacing and submitted in duplicate. The AAAS assumes no responsibility for the safety of manuscripts and photographs or for the statements and opinions expressed by contributors.

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Annual subscriptions: $7.50, domestic and foreign. Single copies, 75¢. Special rates to members of the AAAS.

THE SCIENTIFIC MONTHLY is indexed in the *Reader's Guide to Periodical Literature*.

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Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Microwave Frequency Standard

Accurate to ±0.001 percent for the frequency range of 2400 to 40,000 Mcy/sec, a new microwave frequency standard contains a temperature-stabilized crystal oscillator followed by a multiplier-amplifier chain with outputs at 100, 500, and 1500 Mcy/sec. The standard is supplied with sweep circuits for use with reflex klystron local oscillators. Wave guide units for specified frequency ranges include a harmonic mixer that has been designed specifically for multiplying a crystal-controlled signal, frequency meter, directional coupler, two variable pads, termination, detector, and coaxial adapter. (Narda Corp., Dept. SM, Mineola, New York.)

Refrigeration System

Mobil-Cold portable refrigeration system provides means for depressing the temperature of a vessel or cabinet from ambient temperature to 0°F whenever the factors of mobility and quick installation are desirable. The copper cooling coil is 5 in. in diameter and 8 in. high. The unit is provided with an adjustable thermostatic control, 8-ft insulated hose, air-cooled compressor, and Freon 12 refrigerant. Cooling capacity is 790 Btu/hr. The 45-lb unit operates on 115-volt alternating current. (A. Daigger and Co., Dept. SM, Kinzie at Wells, Chicago 10, Ill.)

Splash Guard

A collar-shaped top molded of Bakelite polyethylene fits over the rim of a paint can. The high collar keeps paint from splashing out of a newly opened can when the paint is stirred and makes it unnecessary to pour off any of the paint. The high collar also permits clean pouring and keeps paint out of the sealing groove on the can. The collar is provided with a straight-edged lip for wiping excess paint off the brush. (NoMus Products, Inc., Dept. SM, 6012 Wayzata Blvd., Minneapolis 16, Minn.)

Organ Builders Manual

An organ builder's manual that describes all the phases of construction of an electronic organ has been published. In addition to information related to console design, tone generators, manuals, pedals, amplification, and accessories, the manual includes a parts-price catalog for amateur builders. (Electronic Organ Arts, Dept. SM, 4878 Eagle Rock Blvd., Los Angeles 41, Calif.)

Magnetic Locator

Magnetic locator that is made by mounting an Alnico magnet in a pencil-shaped aluminum case can be used to locate wall studs, to retrieve small metal objects, and to hold nails that are to be driven. (Dresden Mfg. Co., Dept. SM, 2375 Walnut Ave., Long Beach, Calif.)

Clamp

Saxton has marketed a 1-in. Kant-Twist clamp for small precision work. The clamp combines the features of the C and parallel clamps; the sides are made of high tensile steel; the grooved jaws rotate in one plane. (Saxton Mfg. Co., Inc., Dept. SM, 1517 N. Potrero, El Monte, Calif.)

Liquid Scintillation Spectrometer

Precise counts of beta-emitting samples in solution with liquid phosphors can be made with a new liquid scintillation spectrometer. Isotopes with low beta energies, such as tritium, carbon-14, sulfur-35, and calcium-45, can be counted either individually or in mixtures. The instrument is designed so that the photomultipliers are shielded from room light at all times and so that it is not necessary to manipulate samples in the dark. (Packard Instrument Co., Dept. SM, P.O. Box 428, Lagrange, Ill.)

Variable-Speed Rotator

Variable-speed rotator for serological tests operates at constant speed at any setting within its range of 100 to 220 rev/min. Operating speed, which is maintained by an electric governor, is reproducible. Timed operation from 0 to 30 min is provided. Slides are held by a sponge-rubber pad cemented to a 13- by 13-in. platform. Every point on the surface of the platform rotates through a uniform ¾-in. diameter circle. Bulletin 210. (Eberbach Corp., Dept. SM, Ann Arbor, Mich.)

Fraction Collector

Packard has released automatic fraction collector model 230, which is suitable for both time- and drop-counting operation. The instrument consists of a mechanical unit, turntable 24 in. in diameter, and a phototube unit and control cabinet. The timing system provides collecting intervals for each test tube from 15 sec to 100 min in 15-sec steps. Drop counter permits collection of 1 to 400 drops in each test tube. (Packard Instrument Co., Dept. SM, P.O. Box 428, La Grange, Ill.)

Micromanipulator

Designed and developed by H. H. Hillemann of Oregon State College, a new micromanipulator can be used to produce rapid or slow movement in a straight line as well as a movement of up to 2 in. in each of the mutually vertical planes. Instrument can be attached to either side of any microscope. Adjustment of the stage of the micromanipulator may be required (Custom Scientific Instruments, Inc., 541 Devon St., Dept. SM, Kearny, N.J.)

Research Demineralizer

Ion exchange kit or research model demineralizer consists of two Lucite ion-exchange columns, five jars of cation resins, seven jars of anion resins, a 100-page manual of technical data on the resins, and instructions for operating the device as a mixed- or two-bed ion exchanger. (Barnstead Still and Sterilizer Co., Dept. SM, 256 Lanesville Terrace, Forest Hills, Boston 31, Mass.)

Resistance Thermometer

A new resistance thermometer measures the change, with temperature, in the electrical resistance of 50 in. of 0.002-in. diameter, spun-glass-insulated, high-purity nickel wire. The scale, which is graduated from $-100°C$ to $+276°C$ in $0.5°C$ and $1.0°F$ divisions, is printed on an 89-in. roll of Cronar film. Accuracy from $-100°C$ to $+250°C$ is $\pm 0.5°C$; above $250°C$ it is $\pm 1.0°C$. (Fisher Scientific Co., Dept. SM, 717 Forbes St., Pittsburgh 19, Pa.)

Flame Photometer

Flame photometer by Norelco is designed for rapid sodium, potassium, and lithium analysis in industrial and medical laboratories. A selector switch on the front panel prepares the instrument for either potassium or sodium. The instrument employs separate barrier-layer photo cells and individual filters. Separate sensitivity and zero controls are provided for each element. Readings are made on a 4-in. dial. (North American Philips Co., Inc., Research and Control Instruments Div., Dept. SM, 750 S. Fulton Ave., Mount Vernon, N.Y.)

X-ray Motion Picture Equipment

General Electric is manufacturing x-ray motion picture equipment that was designed by J. S. Watson and S. A. Weinberg of the University of Rochester Medical Center. The apparatus has been designed for use with conventional x-ray equipment; it can be used with either 16 or 35 mm film; speed range is 3¾ to 30 frames/sec. An electronic triggering mechanism synchronizes the x-rays with the camera. (General Electric Co., X-ray Department, Dept. SM, Milwaukee, Wis.)

Ionizing Units

Static electricity on a surface can be neutralized by the alpha particles emitted by newly introduced ionizing units. Units which are made in strengths of 250, 500, and 1000 μc, consist of strips of polonium mounted in stainless steel housing. Size of each unit is 2-3/8 by 7/8 by 7/32 in. (Nuclear Products Co., Dept. SM, 10173 E. Rush St., El Monte, Calif.)

Fineness Tester

Fineness of Portland cement, pharmaceutical powders, and other granular materials can be determined with a new fineness tester that operates on the air permeability method. Bulletin 233. (Precision Scientific Co., Dept. SM, 3737 W. Cortland St., Chicago 47, Ill.)

Nuclear Reactor Simulator

Electronic synthesis of reactor operating conditions for training purposes can be obtained with a new nuclear reactor simulator by Leeds and Northrup. An analog computer solves the differential equations that represent the kinetic operation of a nuclear reactor. The remainder of the assembly includes recorders to measure and chart pile period and linear flux, servo amplifier, rod drive mechanisms, log N amplifier, model reactor core, and other equipment. The simulator can synthesize the operation of several types of reactors. Folder ND46-70-700 (2). (Leeds and Northrup Co., Dept. SM, 444 N. 16 St., Philadelphia 30, Pa.)

Bottle Pump

Only purified air is permitted to enter tank or carboy when the new Barnstead bottle pump is used to pump distilled water. This is accomplished by a Ventgard filter that removes and absorbs various impurities from the incoming air that replaces the liquids being drawn off. The filter removes particulate matter as small as 0.2 micron. Bacteria, such as those that cause tuberculosis, diphtheria, typhoid, tetanus, are prevented from entering the container, as well as vapors and alkali and acid gases. Bulletin No. 136. (Barnstead Still and Sterilizer Co., Dept. SM, 256 Lanesville Terrace, Forest Hills, Boston 31, Mass.)

Windowless Flow Counter

New internal sample counter, a windowless flow counter, may be used for both Geiger and proportional counting of solid samples. A continuous flow of appropriate counting gas must be maintained through the instrument. The physical arrangement of the sample in the chamber makes it possible to achieve full 2π geometry. The instrument is designed for counting alpha particles or low-energy betas. (Packard Instrument Co., Dept. SM, P.O. Box 428, LaGrange, Ill.)

Liquid Leveler

Operating with open containers that hold conductive liquids, a new portable liquid leveler automatically maintains liquid level within ± 0.046 in. of that desired. The portable unit includes electronic relay, stainless steel probes, solenoid valve, nickel-plated copper tubing, and brass needle valve. Current of 3 μa produces positive action. (Blue M Electric Co., Dept. SM, 138th and Chatham St., Blue Island, Ill.)

Magnetic Refrigerator

Any temperature within the range from 1° to 0.25°K can be maintained by a new magnetic refrigerator that operates on the cyclic technique of magnetic cooling. The system consists of a paramagnetic salt and the reservoir to be cooled, suspended in an evacuated chamber that is immersed in a liquid helium bath. Operation is controlled entirely by external magnetic fields. (Arthur D. Little, Inc., Dept. SM, 30 Memorial Dr., Cambridge 42, Mass.)

THE SCIENTIFIC MONTHLY

FEBRUARY 1956

Early History of Radio Astronomy

GEORGE C. SOUTHWORTH

Dr. Southworth, a research engineer at Bell Telephone Laboratories from 1934 until his retirement last year, has studied wave propagation, directional antennas, waveguide transmission and associated microwave techniques, radio astronomy, and earth currents as related to various solar and terrestrial phenomena. He received his training at Grove City College, Columbia University, and Yale University. From 1918–23 he was instructor and assistant professor at Yale University. In 1917–18 he was a physicist with the National Bureau of Standards, and from 1923 to 1934 he was a radio engineer with the American Telephone and Telegraph Company

IT is often asked: What are the important steps that lead to a discovery? Are discoveries invariably predicted by prior theory or experiment or are they more often purely accidental or at best based on a good hunch? Examples of at least two of these three possibilities appear in the relatively new subject, radio astronomy. In one of the cases in question, discovery was indeed accidental, but it is to the everlasting credit of the discoverer that he was sufficiently keen and alert to note the new phenomenon even though it was often masked by other far more obvious effects. Not being content with mere discovery, he then invoked lines of reasoning for which he had no special training to trace his objective to its lair, which turned out to be many many light years away. A less curious radio engineer might well have reported his discovery as a factual but sterile summary entitled, "A new kind of static too small to be of importance to radio communications." Not only is it desirable to record the important steps that led to this discovery, but also such a record represents a very interesting detective story that is quite comparable with the *Adventures of Sherlock Holmes.*

By way of review, it should be noted that present-day radio astronomy includes at least two major domains of exploration. One is our own sun and the other is the general region of the Milky Way. Studies in radio astronomy range in wavelength from perhaps 1 centimeter to about 30,000 centimeters. As Bart Bok of Harvard University has pointed out, this is roughly 12 octaves. Previously, the wavelength range available to the astronomer extended from about 3000 to perhaps 30,000 A, or roughly 4 octaves. Between the two ranges lies a vast region of about 12 octaves. Thus the newer radio techniques have not only given the astronomer a much wider range of wavelengths, but, since they come at a very different place in the spectrum, they have also provided him with an entirely different line of approach. As might be expected, this new approach is now leading to some very interesting results. Results of recent research have been described in a number of places and they need not be repeated here (*1*). Instead, I wish to describe some of the early steps that marked the beginnings of this new field of study.

It might be reasonable to expect that the first work in radio astronomy would have been done on the sun since it is the most obvious of our heavenly bodies. But, interestingly enough, this was not the case. Instead, the first work was done

on an object that at the time must have seemed far less likely—namely, the Milky Way. Not only was this source much more removed in space, but it may well have seemed, at the time, to be a very unpromising direction in which to look for radio waves.

Waves from the Milky Way were first noted by one of my close friends, the late Karl Jansky of Bell Telephone Laboratories. This was possibly as early as November 1930, but it required 10 more months before the identity of the waves was first suspected and still another 11 months before their source could be located in space even approximately. In the case of radio waves from the sun, the discovery occurred much later and there are numerous people, any one of whom could very well have made the first observation. In view of this situation, I have made no attempt to name the discoverer but instead have described one of the more comprehensive sets of observations that were made during the year of discovery, 1942. In both cases referred to, I was either present or I was, figuratively speaking, standing nearby as the discovery was made. Based partly on memory but more particularly on notebook entries, I have in the paragraphs that follow merely played the role of reporter of what I saw and heard.

Extraterrestrial Radiation

As a suitable backdrop for the work of Karl Jansky, it may be well to review the status of radio technology at the time he entered the field. Frequencies in the region 2 to 20 megacycles per second, which were referred to at the time simply as "short waves," were just coming into general use. The vagaries of this new part of the radio spectrum seemed very disconcerting, particularly to those who had previously worked with the older and more orderly long waves. Earlier, the relatively simple Austin-Cohen formula had accounted for most of the known facts of radio transmission, but with the advent of the newer short waves, many new dimensions and many unknowns were brought into the picture. The latter related not only to signal level but also to the level of noise.

In the Bell System, work was in progress at two special laboratories that had been set up at Deal and Cliffwood, New Jersey. At the Cliffwood laboratory in particular, studies proceeded under the direction of H. T. Friis and C. R. Englund, whose interests included not only radio propagation but such related subjects as receivers and antennas. From the first, Friis and Englund stressed the importance of careful experimental work with accurate measurements of both signal level and noise. These quantities were particularly important to them, for the ratio of signal to noise materially affected the design of both the receivers and transmitters that were then under development.

At the longer wavelengths, it had already been found that static was usually the limiting noise (*2*). Accordingly, in the earlier years, it was expected that static might likewise be important in short waves. It turned out, however, that this was only occasionally true. Very often other noises such as, for example, those arising in the radio receiver itself became the limiting factor. Very important questions arose: How intense is the prevailing static? From what directions does it arrive? How frequently does it appear above the noise inherent in the receiver? It was therefore a thoroughly practical point of view that prompted Karl Jansky's supervisors to give him as his first assignment the study and measurement of static.

Long-wave static measurements. At low frequencies (long waves), static level was already a fairly common measurement. Of the several methods of measurement, in considerable favor was the one that had been developed by Jansky's supervisor, Friis. It made use of (i) a double-detection receiver of specified bandwidth together with (ii) a calibrated attenuator located in the intermediate-frequency part of the receiver and (iii) an integrating power-measuring device in the output. The attenuation necessary to adjust the output of the set to a common arbitrary datum level thus became a measure of the relative noise level. This arbitrary datum level was compared from time to time with a single-frequency power source of known level. The necessary attenuation was introduced and recorded by a suitably modified bridge balancing device that was then used extensively in pyrometric work. A slowly rotating coil antenna provided the necessary information about the direction of arrival.

Short-wave static measurements. Part of Jansky's first assignment was the operation and maintenance of the long-wave recorder just described, as well as the analysis of its results. This alone was a sizable job. In addition, he was assigned the more difficult task of adapting this method to the new short-wave range. Although there were great difficulties in adapting this method to the higher frequencies, the higher frequencies brought certain compensating advantages. In particular, sharper directional antennas became available. For Jansky's static measurements, it was proposed that a Bruce array similar to the kind then in use on overseas short-wave radiotelephone facilities be

mounted on a motor-driven rotating platform. With this arrangement, the azimuthal direction of arrival of static could be determined with considerable accuracy. The directional feature was regarded as important, for it seemed desirable to know whether short-wave static arrived from the same general direction as that received on long waves. In addition to the antenna, there were certain other building blocks of the new recorder that had already been designed and built. However, most of the existing equipment was already in use. Therefore it fell to Jansky, a new recruit from the University of Wisconsin who was only 22 years of age, to build these components anew and, furthermore, to make them work as an integrated whole. In addition, there were certain gaps in the over-all system, each of which called for a separate development project. These development projects, together with the analysis of long-wave static data, occupied Jansky almost continuously for the 3 years between 1928 and 1931. No doubt the time seemed even longer, for doubtless he was anxious to get at his task of measuring short-wave static. Little did he realize that a much greater adventure lay in store for him.

Certain feaures of Jansky's short-wave method are shown in the accompanying illustrations. Figure 1 shows a schematic diagram of his circuit arrangement. The top part is a block diagram of the equipment; the bottom part is the circuit of the output integrating arrangement that was called the "rectifier and time-constant circuit." Figure 2 is a photograph of the rotating antenna. The array was turned at the rate of 3 revolutions per hour. Figure 3 shows a representative directional antenna pattern as measured in the horizontal plane. The corresponding vertical-plane characteristic was relatively dull. Thus the beam had roughly the shape of a fan. The final static recording equipment is shown in Fig. 4. On the rack at the left is the long-wave receiver with its recorder at the left center. On the rack at the right is the short-wave receiver. Its recorder is in the right center.

It is of passing interest that Jansky found the static that was expected but it was generally low except when nearby thunderstorms were in evidence. In the winter time in particular, conditions were very favorable for the detection of any unusual noises that might be present; this was the time of year when he first noted extraterrestrial noise. In Fig. 5 there is shown a typical record of extraterrestrial noise as taken on a representative autumn afternoon and evening. Note that as the antenna rotated through the 20-minute cycle, peaks appeared in the low-level noise then pre-

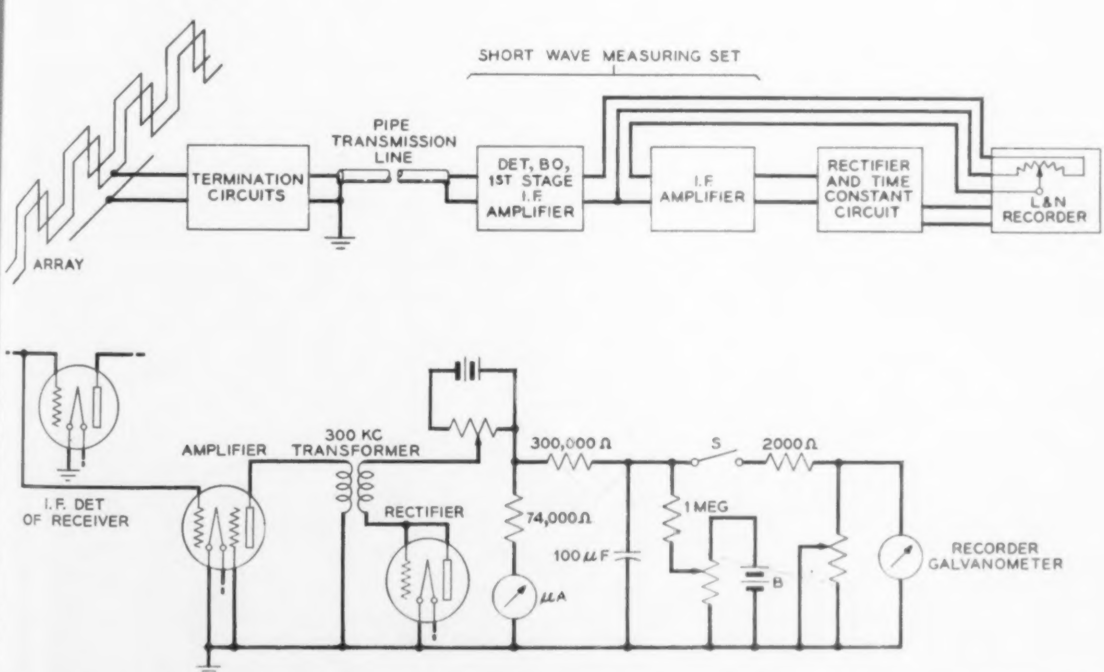


Fig. 1. Circuits used by Karl Jansky at the time of his discovery of radio waves from the Milky Way. (Top) Block diagram of the short-wave static recording system; (bottom) rectifier and time-constant circuit.

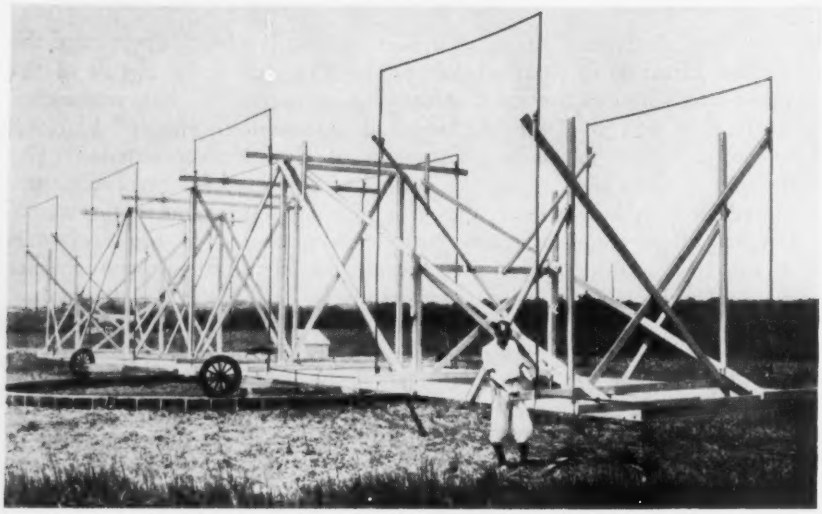


Fig. 2. Karl Jansky and his rotating antenna. Although this antenna was well adapted to the frequencies that were then in use, this type of antenna was far less directive than those that are now used in radio astronomy.

vailing. These peaks continued through the entire 24-hour day. Jansky was, of course, able to identify these peaks not only with time of day but with direction of the compass as well.

As a first step in analyzing his data, Jansky transferred directions of arrival and times of day from his daily records. Monthly means of these data were plotted as a new diagram. Curve *1* of Fig. 6 is a representative example. Note that in the early morning noise came in a general way from the east; at noon it came from the south and at night it came from the west. Thus, the noise at this stage appeared to be coming from the sun. No doubt at this point it all seemed rather simple, and additional data could be expected to bring a more complete verification.

As often happens, the simplicity that presented itself was short-lived, for, when the next month's data became available, they differed materially from those of the previous month, as is evident from Curve *2*. The discrepancy was even more evident when the third month's data (curve *3*) became available. This discrepancy continued with passing months. There is evidence that Jansky expected, at this second stage, that there was super-imposed on the diurnal variation some kind of a seasonal cycle such that the autumn data would appear somewhat like that noted for the vernal equinox. At this point, he was obviously thinking in terms of terrestrial effects. Again he was to meet with surprise, for, as shown in Fig. 7, the discrepancy continued indefinitely. It is easy to see now that this was merely the result of the difference between solar and sidereal time, but to a young electrical engineer viewing a new phenomenon for the first time, this was by no means obvious.

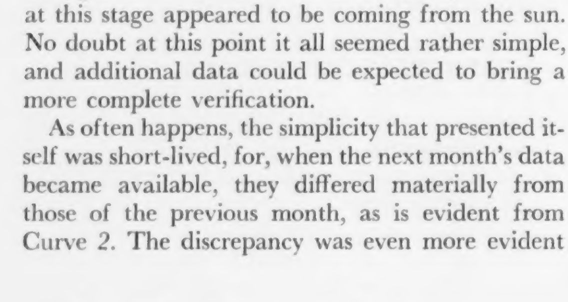


Fig. 3. Horizontal-plane characteristics of the antenna used by Jansky, at a wavelength of 14.6 meters. The vertical-plane characteristic was relatively dull.

Steps toward Discovery

By reviewing Jansky's notebooks and work reports, and from other sources of information, we may piece together the more important steps that led him to his very important discovery. First we find that he reported for work at Bell Telephone Laboratories in New York on 20 July 1928. A month later he was at the Cliffwood laboratory working on a static receiver. This was no doubt the long-wave recorder that has already been referred to. It operated at a frequency of 44.12 kilocycles per second. In September 1928 he recorded in his notebook that he had been working on the calibration of a long-wave static receiver but that he would shortly start work on a similar short-wave receiver. Work on the long-wave recorder apparently continued through the autumn and early winter months.

In March 1929 he records in his notebook that

he is studying antenna arrays and is designing an array for short-wave use that can be mounted on a turntable. In addition, he tells of discussions with his supervisor, H. T. Friis, about a short-wave receiver that is to be built soon. This, no doubt, marks the beginning of the particular work that led ultimately to the discovery of extraterrestrial noise. It will be noted that this was 2 years in advance of the discovery itself.

Throughout the summer of 1929 there are records of work on the short-wave receiver and troubles with it. There were, for example, singing amplifiers and stages of the amplifier in which the response was nonlinear. These were traced to feedback difficulties that were corrected only after the several circuits were enclosed in separate metal compartments with lead wires and even batteries appropriately shielded. Also during the summer, plans were being drawn for the antenna array. For this period, the date 24 August 1929 is especially significant, for the record states: "Mr. Sykes will start work on the merry-go-round next Monday."

Entries relating to the short-wave recording system were rather infrequent during the autumn. However, it is evident that the array and mounting were nearly complete by 10 December 1929. It is reasonable to assume that a considerable portion of this period was spent on the long-wave recorder and the analysis of its data. About this time another deterrent appeared. It was announced that the entire Cliffwood laboratory, of which Jansky was a part, was to be moved to a point near Holmdel, a distance of perhaps 5 miles. This meant that Jansky's antenna setup, including the array complete with cement foundation and track, would have to be reassembled at the new location. No doubt Jansky received the usual pious promises that there would be a minimum of delay, but, as many people know, moving schedules and facts never seem to match. Records show that the move was made in the early part of 1930 but that the array was not restored to good running order until late fall. This represented a delay of nearly a year.

A work report for November 1930 indicates that the array was by then completed and that as of that date static seemed to come from 13 degrees south of west. Jansky remarked that there was no disturbance evident on the weather map. Therefore we wonder whether this may not have been extraterrestrial noise. It was certainly not so recognized. The winter months of 1930–31 were apparently spent on other matters, but an entry dated 28 February 1931 says: "Static on short waves was not recorded this week but was observed several times by ear. The most common direction of arrival was slightly north of east." Unless there was an error in recording directions, this could hardly have been extraterrestrial noise, for during the usual working hours of February the most likely direction would be southwest. An error of 180 degrees might easily have been made, however, and after all it is possible that Jansky was observing the radiation for which he is now so well known. In March 1931, he reported heavy short-wave static coming from the south but sometimes from south southeast and even east. Since March is a month of low thunderstorm activity, we suspect that he was again observing extraterrestrial noise.

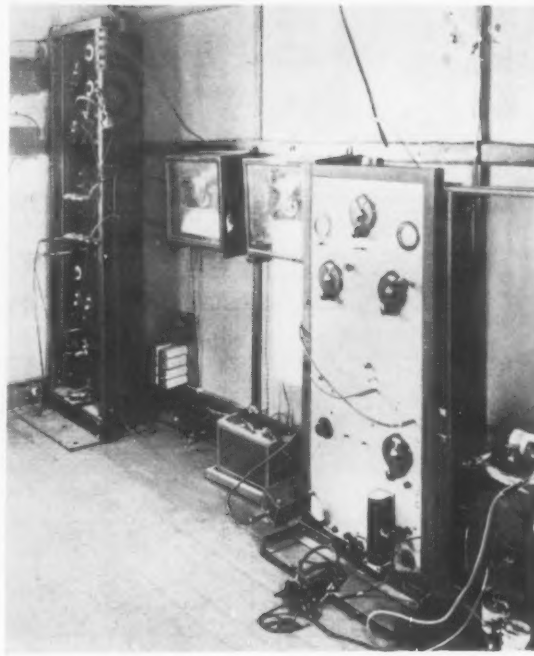


Fig. 4. Jansky's receiving apparatus. The long-wave apparatus is on the left, the short-wave apparatus on the right.

Much of the summer of 1931 was evidently spent on a receiver for ultrashort-wave static that he had apparently been asked to build. Again Jansky was encountering a familiar deterrent. He was being asked to start a new job before the old job was finished. This difficulty notwithstanding, we find in his August 1931 report that he is back on his old job. In this same report, he makes a very significant statement as follows: "The 14.5-meter static recording system has been overhauled; it was put in operation about the middle of the month and has run almost continuously since. Static has been received from nearly every point of the compass at some time or other while the system has been operating; however, most of the

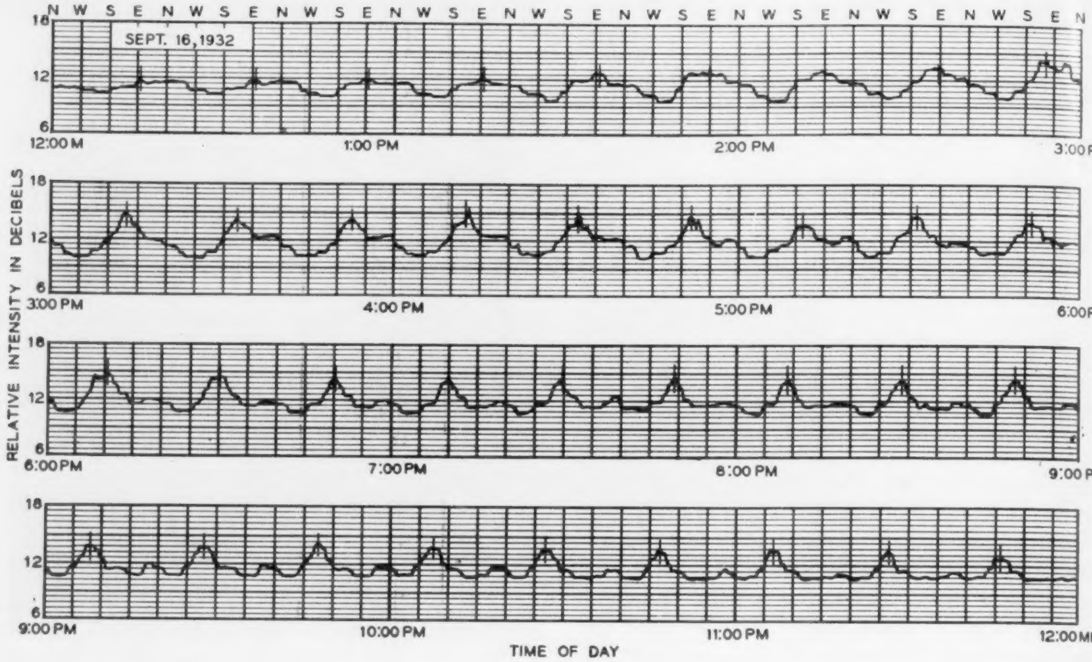


Fig. 5. Typical autumn record of waves of extraterrestrial origin. As the antenna was rotated through its 20-minute cycle, peaks appeared in the low-level noise that was then prevailing.

static has come from directions varying between southwest and southeast. . . . Static was strongest, during the month, just before, during, or just after an electrical storm; however, nearly every night that the receiver was run, static was received from a source that apparently always follows the same path. Early in the evening, about 6 P.M., this static (it has always been quite weak) comes from the southeast; by about 8 P.M. it has slowly moved to the south; by midnight it comes from the southwest; and by 3 A.M. it comes from the west. The reason for this phenomenon is not yet known, but it is believed that a study of the changes in the range of the receiver in different directions and for different hours of the day, together with a study of the known thunderstorm areas of the world, will reveal the cause." It is quite evident that at this stage Jansky was recording extraterrestrial noise, but as yet he was still trying to identify it with sources of terrestrial origin.

In the September 1931 work report, it is stated: "The 14.5-meter recorder and rotating array have been run constantly day and night during the month. As during last month, the strongest static came during the period of thunderstorm activity. It reached a peak of 3.68 μv/m at 4 P.M. September 14. The usual 'night-time' static has been recorded nearly every night during the month; however, instead of continuing on through the night till 4 or 5 A.M., it now disappears about midnight. Occasionally it will reappear again for a short time about 4 A.M. A new static source is now developing late in the morning, beginning about 8 A.M. and continuing till noon. Weak static has been heard several days lately coming from almost due south."

In the October work report, it is stated: "The usual night-time static was recorded during the early part of the month, but near the middle of the month it dropped to an intensity below that of the first circuit noise and could be recorded no longer."

In the November report, Jansky says: "The usual night-time static is still being observed."

By January 1932, things were becoming very interesting indeed. It is recorded: "The short-wave rotating array and static recorder have been run almost continuously during the month, and some very interesting results were obtained. Thunderstorm static was almost completely absent, but there was and still is present a very steady continuous interference; the term *static* does not quite fit it. It changes direction continuously throughout the day, going completely around the compass in 24 hours. During the month of December, this varying direction of arrival followed the

sun almost exactly, making it appear that perhaps the sun causes this interference or at least has something to do with it."

In February 1932 he records: "The short-wave rotating array and static recorder were run about 2 weeks last month during which time records were made of the steady hiss-type of static. The direction of arrival is no longer following the direction of the sun as it did in December and the first part of January, but precedes it now in time by as much as an hour."

In this same report, Jansky informs us that he is preparing for the forthcoming April meeting of the International Scientific Radio Union (URSI) a paper entitled "Directional studies of static on short waves" (*3*). This was the paper that first reported extraterrestrial noise, but because data for only the first 3 months of the year were included, the source of this noise was not yet established. In this paper, the day-by-day shift was reported, but it was tentatively attributed to some kind of seasonal effect. Jansky states quite correctly that more data are needed.

Apparently Jansky watched with interest the continued shift of the diurnal characteristic from month to month during the early summer and through the summer solstice, for it was this that would mark the seasonal effect expected. In his August report, he stated: "The short-wave rotating array and recording system were operated over every week end during the month, and many good records of hiss-type and thunderstorm static were obtained. As yet, these records have not been replotted, but the indications are that the curve for the hiss-type static (direction of arrival plotted against time of day) is not going to shift in accordance with the position of the sun as was expected. Instead of returning with the sun to the same position it had last spring, it is continuing to shift in the same direction that it has shifted throughout the summer."

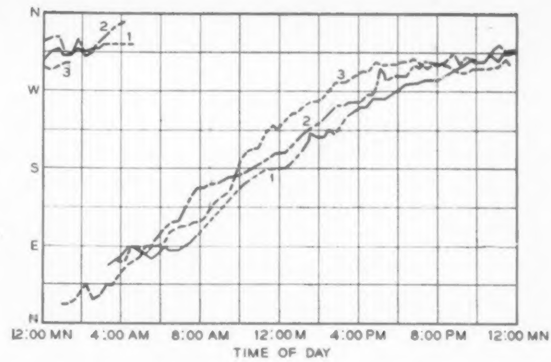
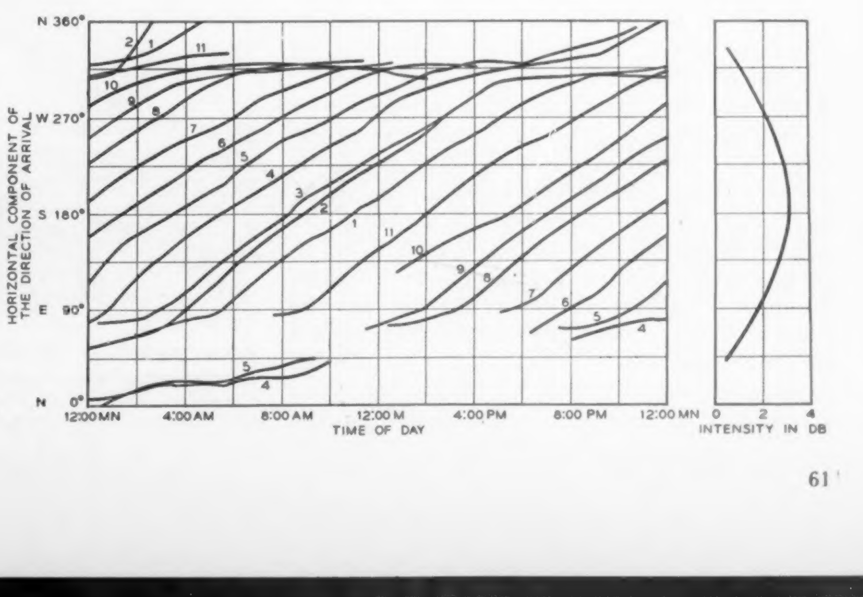


Fig. 6. Direction of arrival versus time of day of waves of extraterrestrial origin. Wavelength 14.6 meters. The three curves were obtained in successive months.

It is to be noted at this point that Jansky was quick to note that the trend he was observing followed no simple seasonal cycle, but apparently it had not yet occurred to him that the source was of extraterrestrial origin. These facts notwithstanding, July and August 1932 probably marked a turning point leading to the ultimate discovery of the source.

The work reports for September through November contain no significant data, but interviews with Jansky's associates of that time indicate that much was going on in his mind. He discussed his results with many people, including me. It is to be noted, however, that I was at that time in another company of the Bell system and therefore was not closely associated with Jansky. Others who were more intimately associated with him were Friis, his supervisor; Bruce, who was then working on short-wave antennas; and Beck and Crawford,

Fig. 7. Representative data concerning extraterrestrial noise for the year 1932, showing direction of arrival of waves. *1*, 21 Jan.; *2*, 24 Feb.; *3*, 4 Mar.; *4*, 9 Apr.; *5*, 8 May; *6*, 11 June; *7*, 15 July; *8*, 21 Aug.; *9*, 17 Sept.; *10*, 8 Oct.; *11*, 4 Dec. The curve at the right shows the noise intensity in decibels above the set noise.



who were working on receivers. One of his associates who was able to help perhaps most was A. M. Skellett, who is now director of color television of Tung-Sol Electric, Inc. Skellett had recently completed his graduate work in astronomy at Princeton University and of course was altogether familiar with the subject of celestial mechanics. It is Skellett's recollection, now attenuated by nearly 25 years of time, that he suspected then that Jansky's phenomenon was following sidereal time and that he accordingly directed Jansky to textbooks giving standard methods of calculation.

We have thus far found no record of the exact time when these calculations were made, but it was almost certainly sometime between August 1932 and December 1932, for in the latter monthly review, Jansky states that at Southworth's suggestion he had replotted several of the old records and one group of the new records. He says: "The curves obtained show conclusively that the noise I have termed 'hiss-type static' comes from a direction that always lies in a plane that is fixed in space." I do not remember the incident to which he refers, but the suggestion was obviously merely one that he reach back into the previous year for fragmentary data to complete the annual cycle. Later, as more reliable information became available these temporary data were replaced.

With the completion of the December 1932 records, Jansky had at hand data covering the entire calendar year of 1932. These form the basis for Fig. 7. At this point Jansky prepared the well-known paper describing his results (*4*). Other papers describing other aspects of his findings followed (*5*). Somewhat later, he was assigned to other duties and his work in radio astronomy came to an end. His interest nevertheless continued.

It is of interest that, following Jansky's pioneering work, the study of extraterrestrial noise passed to Grote Reber, another lone worker in the field. Working in his own back yard observatory in Wheaton, Illinois, under the severe handicap of carrying on at the same time full time employment, Reber was able to extend Jansky's results very materially. In particular, he operated at higher frequencies and introduced into radio astronomy the idea of the paraboloidal antenna, thereby obtaining sharp directivity in mutually perpendicular planes. As many readers know, his work is still in progress in Hawaii and Tasmania under far more favorable conditions. Its importance, through the years, speaks very eloquently for itself. Not only has he made important contributions, but he has also more-or-less singlehandedly maintained for years a continuity of data that, together with Jansky's work, gives us nearly a quarter-century of nearly continuous radio astronomy. Indeed, when it is written, Chapter 2 of the history of radio astronomy, which includes Reber's part, promises to be quite as interesting as Chapter 1.

Radio Waves from the Sun

It will be noted that Jansky's discovery was one in which an experiment set up for another purpose led to the discovery of a phenomenon that at the time was altogether unknown and even unsuspected. In contrast, radiation from the sun was a phenomenon that had long been expected. Both the principles of radiation from incandescent bodies and resistance noise, perhaps two aspects of the same phenomenon, had pointed to sources of energy of this kind. True enough, there was doubt in some minds that the laws of radiation that were formulated for the visible region of our frequency spectrum could be expected to hold in the centimeter region. In addition, similar doubts may have surrounded the consideration of an incandescent source like the sun, 93 million miles away, as the equivalent of a circuit element in a transmission system. Yet there was a plausibility in either of these lines of reasoning that was inviting.

The idea that the sun might be a possible source of radio waves certainly existed at the time of Oliver Lodge's early work with wireless. We find in a record of a lecture that he gave before the Royal Institution of Great Britain in 1894 that he expressed the hope to "try for long-wave radiation from the sun." Later, he reported that the experi-

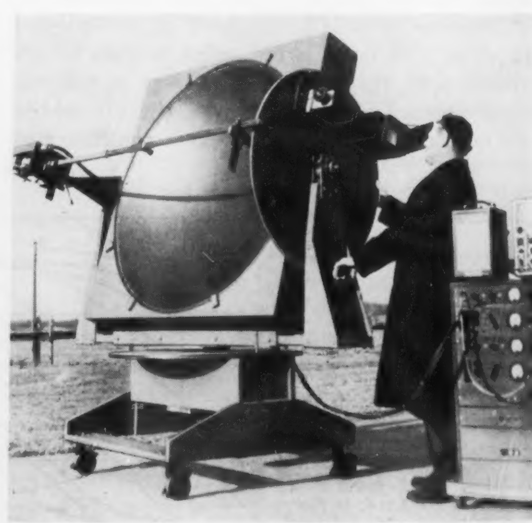


Fig. 8. Early apparatus used in measuring the intensity of radio waves from the sun. The camera with telephoto lens shown mounted on the side was not actually in use when these experiments were made.

ment had been tried and that no such radiation had been found (*6*). Bearing in mind that there was then no amplifier and that the relatively crude nickel-filings coherer was still the accepted receiver, it would appear that at best this hope was a bit optimistic.

It seems very probable that, in the 60 years that have followed, many people must have thought of looking for radio waves in the sun; they may indeed have done so. The outlook for many years was not, however, attractive. For calculations based on black-body theory indicated that, even at the highest radio frequencies and with antennas of the highest directivity then available, the intensity would probably be far below the noise level prevailing in the local radio receiver. This discouraging outlook notwithstanding, radio waves from the sun must have remained an interesting possibility.

Nearly 25 years ago at Bell Laboratories, I became interested in the subject of waveguides and in this connection evolved new cavity techniques that subsequently became very useful in microwave radio work. This work had an important bearing on the solar problem, for it provided important building blocks for translating our existing double-detection receiver methods, which were then poised at a frequency of 100 megacycles per second, on up the frequency scale. This more advanced double-detection receiver work had been under development since 1938 or before.

After we had groomed a receiver of this kind to the point that it had relatively low first-detector noise, it was natural that we should point the antenna at the sun. This was first done at my request by one of my associates, A. P. King, on 29 June 1942. We found, as expected, that the solar noise represented a small increase in the total noise output. This experiment was performed first at a frequency of roughly 9400 megacycles per second (wavelength, 3.2 centimeters), but a week or two later it was repeated at 3060 megacycles per second (wavelength, 9.8 centimeters). Because the war was on, it was difficult to find time to work on solar observations. It was possible, however, to make many measurements between June and October. For the most part they were spread at closely spaced intervals over the entire daylight period. The days were distributed more or less randomly as weather conditions and the pressure of other work permitted. Substantially the same power was received at sunrise and sunset as at noon. For this reason, it was concluded that the earth's atmosphere had no appreciable attenuating effect. When the results obtained in October were compared with those of June, we found no very obvious seasonal effect.

Fig. 9. Experimental radio sextant of current design built by the Collins Radio Company. [Courtesy Collins Radio Company]

Because Jansky's interesting results were still fresh in mind, some time was spent looking at the Milky Way, particularly in the direction of Sagittarius, the region that Jansky had previously reported as the probable source of extraterrestrial noise. Nothing was found. Although our study of the Milky Way was not as complete as we should have liked, we did make observations over one complete 24-hour cycle, at times using a standard star map as our guide.

During the year that followed, development work continued toward higher and higher frequencies until by June 1943 there was available a beating oscillator and first detector for frequencies of about 24,000 megacycles per second (wavelength, 1.25 centimeters). This is near the present upper frequency range of radio astronomy. The measurements during this second summer were confined mainly to 9400 megacycles per second and to the newer frequency of 24,000 megacycles per second. At the lower frequency most clouds were sensibly transparent, but at the higher frequency there was substantial absorption. Indeed, there was conclusive evidence that at the higher frequency the atmosphere, even on a clear day, was absorptive.

During the years when this work was in progress, two or more technical reports describing our work were prepared. These were circulated through the established wartime channels to all those who were authorized to see such material. A few copies went to agencies less intimately related to the wartime radar effort—for example, to the Harvard College

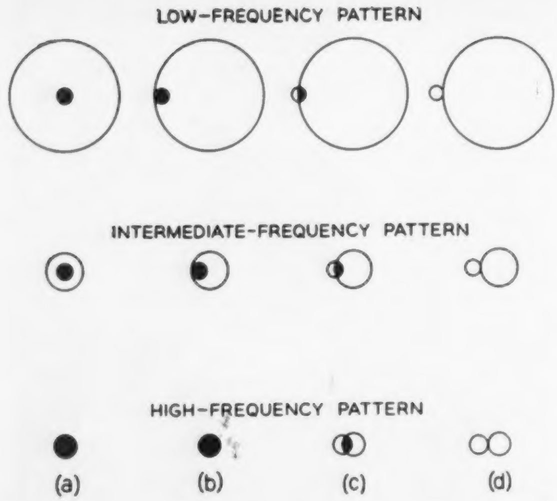


Fig. 10. Series of diagrams comparing the apparent diameter of the sun (solid black portions) with the directive pattern of the antenna for various frequencies. (Top) Low-frequency pattern (3000 megacycles per second); (middle) intermediate-frequency pattern (9400 megacycles per second); (bottom) high-frequency pattern (24,000 megacycles per second).

Observatory. Many copies went to the British War Office for circulation, not only to their own people in England, but to their colonial possessions as well. Later the British War Office requested additional copies. In addition, many of the current visitors to our Holmdel laboratory saw the work while it was in progress. Included were several who have subsequently become very active in this field —for example, A. G. Bowen and J. W. Pawsey of the now famous Radiophysics Laboratory of Sydney, Australia.

As soon as it seemed reasonable to do so, an effort was made to obtain the necessary military releases for publication in an accredited journal, but many difficulties were encountered. These were possibly prompted by the fear that the paper might supply the enemy with useful information about the frequencies and techniques used in Allied radar. After repeated attempts to obtain clearance, which extended over a period of a year or more, we omitted references both to particular frequencies and to details of our apparatus. This time we succeeded in getting the releases. The deletion of pertinent facts naturally detracted materially from the value of the article, but it seemed to be an acceptable compromise. Publication followed in April 1945 (*7*). The results, when they were modified to take into account an inadvertant error, gave about 20,000°K as the effective temperature of the sun.

Figure 8 shows the physical arrangement that was used in these experiments. The antenna system consisted of a 5-foot-diameter paraboloid together with a waveguide pickup that was located at the principal focus. The waveguide led to a box on the side that contained the first detector and beating oscillator. The intermediate-frequency power so obtained (at 60 megacycles per second), was connected to a nearby amplifier and second detector. The possibility of using this device as a sextant in cloudy weather was not overlooked (*8*). It is understood that the U.S. Navy has recently had under test an experimental sextant of this kind (*9*). One of the current models built by the Collins Radio Company is shown in Fig. 9.

There is shown in Fig. 10 a series of diagrams that give, approximately to scale, the apparent diameter of the sun as measured by optical means. Outside is drawn a circle corresponding roughly to the locally measured pattern of the paraboloidal reflector used as the antenna. Note that for the lowest frequency (3000 megacycles per second) this is about three times the diameter of the sun; for the middle frequency (9400 megacycles per second), it is roughly twice the diameter of the

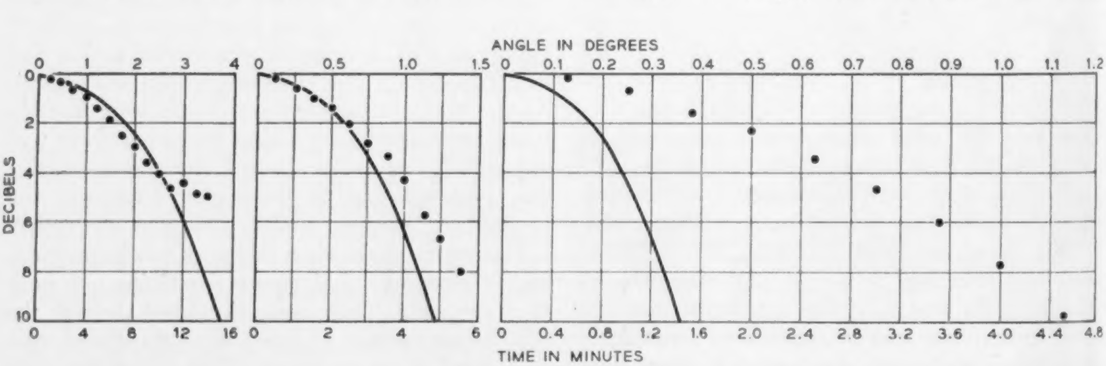


Fig. 11. Apparent diameter of sun measured by radio methods compared with locally measured pattern of the antenna for various frequencies. (Left) low frequency (3000 megacycles per second); (middle) intermediate frequency (9400 megacycles per second); (right) high frequency (24,000 megacycles per second).

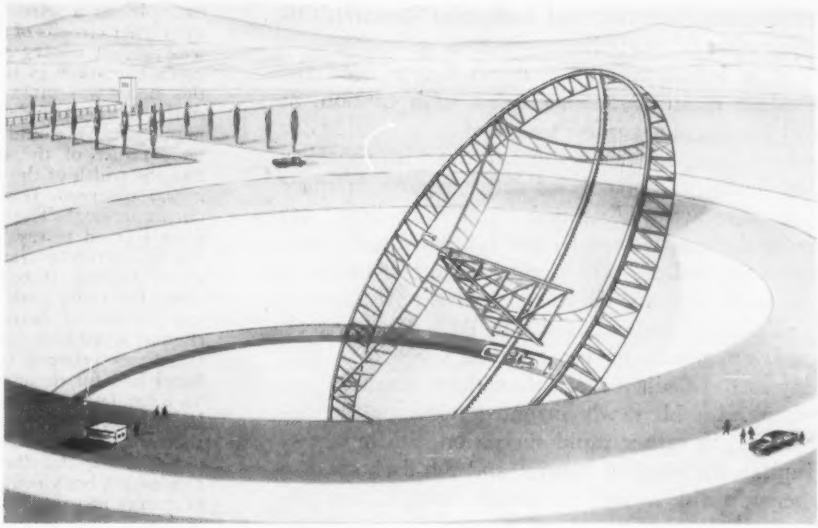


Fig. 12. One favored design of a radio astronomer's telescope. The reflector moves on tracks inside a hemispherical hole in the ground. A very large excavation is required, but some of the structural and windage difficulties are overcome. [Courtesy Division of Radio Physics, Commonwealth Scientific and Industrial Organization of Australia]

sun; and for the highest frequency (24,000 megacycles per second), it is approximately the same diameter as the sun. It might be expected that in the first case the sun's disk, being small compared with the diameter of the directive pattern, would behave much like a point source. Hence, the locally measured pattern and the solar pattern might be expected to be approximately the same. In contrast, we might expect for the last case that, since the two diameters are roughly the same, the solar pattern would be somewhat larger than the locally measured pattern, but perhaps larger by only a factor or two. The facts are otherwise.

One of the routine measurements consisted of directing the antenna toward a point immediately ahead of the sun. Then, with the antenna fixed, a number of evenly spaced measurements of received noise power were made as the sun traversed the aperture of the antenna. Representative data are shown in Fig. 11. Note that for the lowest frequency (3000 megacycles per second), the solar pattern has approximately the same angular width as the locally measured pattern, as was expected. For the middle frequency (9400 megacycles per second), the solar pattern is perceptibly larger than the locally measured pattern. Finally, for the highest frequency (24,000 megacycles per second), the solar pattern is considerably larger than the locally measured pattern. Indeed, it is much larger than the factor of two that was expected. This seemed to say that the apparent diameter of the sun increased with frequency (*10*).

It may be of interest that at the time of publication we were very much interested in radio astronomy and had under consideration not only larger antennas but also suitable equatorial mountings. Although we had gained a great deal of definition through the use of very short waves, we were only approaching the point where particular portions of the sun's disk could be explored. In November 1944 I discussed the matter of mountings with authorities on the subject such as Harlow Shapley of the Harvard College Observatory and Charles Elmer of the Perkin-Elmer Corporation. Covetous eyes were even turned toward Palomar! It was, however, already evident that ultimately a structure would be needed that in size would far overshadow anything so far built, even Palomar. Very soon, this work came to an end, for I was assigned to another task that was possibly more important but certainly far less interesting. By the time I returned to my original interest, similar work was in progress at a number of other places and it seemed inadvisable to break afresh into a field that was already in capable hands.

It is interesting that from the very humble beginnings outlined here there should have evolved in a relatively short time a very spectacular new field of science. Even one who is moderately familiar with the steps that have so far been taken finds it hard to believe that so much could be accomplished in so short a time. No longer is the modern radio astronomer content with a paraboloidal reflector having an aperture of a mere 5 feet; he has passed rather rapidly to diameters of 10, 50, and 250 feet, and now we are told that he is looking hopefully toward much larger apertures. There is shown in Fig. 12 in very preliminary form one of several possible designs for a giant radio telescope. This one, considered specifically in connection with a diameter of 250 feet, has been proposed by the Division of Radiophysics of the Com-

monwealth Scientific and Industrial Research Organization of Australia.

It is interesting too that no longer need the modern radio astronomer speak with caution, as did Jansky, of a *possible* source of noise outside our solar system. Instead he now speaks with considerable certainty not only of active regions in space but of rather well-defined radio stars. Some are quite dark as viewed by the human eye. Indeed, following Reber's very creditable start at mapping the radio heavens, the astronomer is now filling in a substantial amount of detail. With his new tools he is apparently having quite as much of a field day as did Galileo more than three centuries ago when, with his newly invented telescope, he discovered, in rather rapid succession, the moons of Jupiter, the rings of Saturn, and the dark spots of the sun's disk as well as certain mountainous features of the moon.

References and Notes

1. B. J. Bok, *Sci. Monthly* **80**, 333 (1955).
2. As most people know, static gives rise to the "snapping and cracking" sound sometimes heard from a radio receiver. When Jansky entered the scene, ideas about static were not yet altogether clear. The idea was already taking form, however, that most static originated in electric discharges between adjacent clouds or possibly between clouds and ground. This view was easy to accept, for one of the earlier forms of wireless transmitters had used, as its source of power, electric discharges between an elevated antenna and ground. The studies of static then in progress included the measurement of not only the intensity of static but its direction of arrival as well. Attempts were made to correlate these two data with known areas of thunderstorm activity. One apparent source of static was in the general region of the Caribbean Sea. It was also found early in the history of radio that the ignition systems of automobiles and nearby power lines were in effect miniature transmitters and that they too constituted a source of noise. These noises were sometimes confused with static. Later, as communications research developed, it was shown that in any communications path—for example, in a wire transmission line or possibly in the earlier circuits of a sensitive radio receiver—there was present a very subtle source of noise that was much like static in superficial appearance. Although this noise was often extremely low compared with static, it might under certain circumstances be very important. This kind of noise depended on both the temperature of the element in which it originated and the width of the band of frequencies over which it was observed. It was sometimes known as "first-circuit noise." The theory underlying first-circuit noise seemed to say that the elemental source need not be merely a transmission line or a circuit element. Indeed, it could be a hot body somewhere along the radio path such as, for example, a glowing furnace or perhaps the sun. This new theory showed a striking resemblance to an older theory, sometimes referred to as "black-body theory." The latter had for decades been invoked to explain why an incandescent body gave off not only visible light, but also radiations much longer and also much shorter than those that can be detected by the human eye. Indeed, this theory seemed to say that an incandescent body could give out microscopic amounts of energy at wave lengths even as long as those used in radio. It is interesting that among these various possibilities there was at that time no very good reason to believe that any considerable amount of noise could arise in the Milky Way. It was in this welter of rather confused ideas about static, man-made noise, and thermal noise that Jansky was working as he isolated a fourth type of noise and thereby set off a chain reaction of speculations and investigations in the neighboring field of astronomy.
3. K. G. Jansky, "Directional studies of static on short waves," *Proc. Inst. Radio Engrs.* **20**, 1920 (1932).
4. ———, "Electrical disturbances apparently of extraterrestrial origin," *ibid.* **21**, 1387 (1933).
5. ———, "Radio waves from outside our solar system," *Nature* **132**, 66 (1933); "Note on source of interstellar interference," *Proc. Inst. Radio Engrs.* **23**, 1158 (1935). In addition, there were 20 or more semipopular articles on extraterrestrial noise. The technical articles appeared in abstract form in many other periodicals.
6. O. Lodge, *Signalling across Space without Wires* (Electrician, London, ed. 4).
7. G. C. Southworth, *J. Franklin Inst.* **239**, 285 (1945).
8. ———, U.S. Patent 2458654, filed 27 Dec. 1943.
9. D. O. McCoy, Rept. No. CTR-133, presented at the annual convention of the Institute of Radio Engineers in New York, 21–24 Mar. 1955.
10. Measurements made by subsequent observers seem to indicate that the opposite is the case.

No man will ever comprehend the real secret of the difference between the ancient world and our present time, unless he has learned to see the difference which the late development of physical science has made between the thought of this day and the thought of that (of ancient Greece), and he will never see that difference, unless he has some practical insight into some branches of physical science.—Thomas Henry Huxley.

Challenge of Arid Lands

B. T. DICKSON

Dr. Dickson, chairman of the Council of Canberra University College, Canberra, Australia, received his training at Queens University in Kingston, Ontario, and at Cornell and McGill universities. He taught economic botany at McGill University and from 1927 to 1951 was responsible for the development of the Division of Plant Industry of the Commonwealth Scientific and Industrial Research Organization of Australia. He is now a member of the Advisory Committee of Arid Zone Research of the United States Educational, Scientific and Cultural Organization. This article is based on an address given 28 April 1955 at the International Arid Lands meetings, sponsored by the AAAS, and its Southwestern and Rocky Mountain Division, at the University of New Mexico in Albuquerque. Reference is made to several of the papers that were presented at the meeting.

ARID lands, wherever they may be located, especially if they are hot, are characterized by intense blue skies by day, immense distances in a shimmering atmosphere, sparse vegetation and still sparser animal and human population, and a limited and erratic rainfall of less than 10 inches in a good year. Yet we recall that great civilizations were developed in arid areas crossed by great rivers, such as the Tigris and Euphrates, the Indus, and the Nile.

How big is the challenge as far as area goes? It is difficult to get precise figures, but it is generally believed that the total land surface of the earth is of the order of 25,000 million acres; of this at present, about 2500 million, or 10 percent, are under some form of cultivation. But it is also estimated that about 6400 million acres are arid—in other words, about one-quarter of the total land surface of the earth. That is, the arid area is just over 2.5 times as large as the presently cultivated area.

The end of World War I saw the end of large-scale settlement in, and development of, new lands by pioneering individuals in whom the spirit of adventure or the desire for a freer life was strong. There came with World War II a startling realization of the precarious way in which most nations live—a way fraught with all the explosive possibilities for further bitter struggles among peoples.

Today we know that Malthus was just ahead of his time, and we have to ask ourselves whether adequate food requirements of people can be provided from present sources with all the technologic experience available to us. We suggest that two possibilities arise: (i) a reduction in the rate of growth of the population of the world; and (ii) an increase in production of foodstuffs, not only just to feed people on a minimal diet, but to feed them on a diet nearer to the optimal. With the control of the rate of population growth arid zone specialists have little or nothing to do. However, arid zone specialists do say, with regard to the second possibility, that it is possible to increase world food supplies by increasing production from present areas and by bringing into production additional land that is at present uneconomically used.

By application of technologic knowledge to the fullest extent in what are at present underproducing areas, it is possible to obtain a great increase in food production. India, for example, possesses irrigation works on a great scale; and nowhere else in the world is so large a population dependent on irrigation for food supplies; yet it is estimated that less than 10 percent of the runoff of her rivers is utilized.

When we come to consider the possibilities in arid lands, it is recognized that the efforts of individual growers can play but a small part in the development of new areas of production or the reestablishment of production in great areas that used to be fertile in ancient times and are now out of use. I refer to the millions of acres in the valleys of the Tigris-Euphrates, the Indus-Chenab, and the Nile rivers, and in the dry north of Ceylon where the remains of ancient irrigation channels and reservoirs are still to be seen. It is estimated that in Latin America more than 12 million acres are susceptible of development, and an area bigger than Egypt's productive land is said to be available in the middle Niger Valley. The reestablishment of ancient areas and the development of new areas require the joint efforts of research institutions, governments, and the instrumentalities of the United Nations such as the Food and Agriculture Organization, the World Health Organization, and

the World Meteorological Organization as well as the international financial authorities.

Let us now consider some of the problems with which those charged with arid land development have to deal. I propose to discuss them under the following heads—water, soils, plants, animals, and man—presenting what must obviously be a very sketchy outline of some of the salient features of each.

Water

Water is placed first for obvious reasons and adequate information about the water resources of a region is essential to a safe usage of that water for full development in food production, domestic use, and industry. In the desert one conserves every drop of water for the maintenance of life; in great urban centers one turns a tap and water flows, but sometimes restrictions are placed on turning those taps. In other lands the fresh water from great mountain ranges flows several thousand miles to the sea and constitutes a fresh water delta of tremendous size in the ocean.

Whence comes the supply, great or small? The answer is rainfall, which is the beginning of what is called the hydrologic cycle and is the controlling factor in the hydrologic cycle. Some of the rain soaks into the ground, some runs off in streams, some is evaporated, and some is transpired by vegetation. That which is evaporated or transpired by plants, like stream waters, may travel great distances, but ultimately it again falls somewhere as rain, snow, hail, fog, or dew. In tropical areas rainfall may actually be beyond the capacity of man to use, as it is in the Amazon Valley; but in arid and semiarid areas rainfall is low and every effort must be made to conserve usage to the best ends. This applies even when an arid area is using imported precipitation, as in Egypt, where the Nile Valley is dependent in the main for its supply of water on the rainfall in the Abyssinian highlands.

One of the first problems in the hydrologic cycle of arid areas is that of accurately measuring precipitation. Because rainfall is low anyway, it can be very local and extremely sporadic; this erratic distribution both geographically and in time makes for considerable discrepancies in accurate measurement .

During consideration of the subject of rainfall, thought naturally turns to the fascinating possibility of rain making, and a preliminary report by the World Meteorological Organization entitled "Artificial inducement of precipitation with special reference to the arid and semiarid regions of the world," prepared by the technical division of the WMO secretariat from reports received, should be noted:

> From the consideration of the regional reports quoted in this paper, the following conclusions might be drawn:
>
> 1) Operations which have so far been carried out have produced results that could be termed, at best, inconclusive; neither the complete failure of the methods employed nor the certainty of getting substantial increases of rainfall, have been demonstrated.
>
> 2) The most favourable meteorological conditions for the artificial inducement of precipitation are to be sought in regions and during seasons where natural precipitation is most likely.
>
> 3) Present day techniques, either "cold" or "warm" cloud seeding, have very little value, if any, in augmenting the precipitation in areas of very low rainfall or during dry periods in regions of normally medium rainfall.
>
> These tentative conclusions should not be taken as the expression of a negative attitude toward studies and experiments on the artificial modification of clouds and precipitation. On the contrary, they indicate that further effort is necessary.
>
> It is therefore recommended that: (a) new scientifically designed and rigorously checked experiments be undertaken in all regions where there is a possibility of success; (b) precise methods of evaluating the amount of precipitation resulting from such experiments be developed; (c) in all research experiments and applied operations, the collaboration of the meteorological authorities be sought, in order to ensure the greatest reliability in conducting the experiments and assessing the results; (d) information on all projects already carried out or those in operation now be released and made available to all scientific workers, putting development of science before commercial and other interests.

It is well known that advanced civilizations formerly occupied what are today arid regions. Excavations show the remains of reservoirs, canals, fortifications, and human habitations; these presume an intensive and extensive cultivation by large populations. Such is the case in India, Pakistan, North Africa, the Near East, and even in the desolate region of Lob Nor in central Asia, where there are remains of oasis towns and irrigation works. The disappearance of these civilizations may have been brought about by severe climatic changes or by the doings of man not for the benefit of mankind.

Jean Tixeront, chief engineer of public works in Tunis, in asking whether it is possible to forecast weather over long periods, has pointed out that we do not yet have sufficient reliable records but has stated that in Tunisia use is made of one of na-

ture's records in the growth rings of trees and one of man's in archeological studies. The Meteorological Service of Tunisia studied the climate of Ain Draham from 1736 to 1955 by examining the growth rings of an oak tree. The inference drawn was that from 1736 to 1790 there was significantly more rain than there was later; this seems to be confirmed by historical documents that refer to abundant crops in the 18th century.

Tixeront considers that a study of the ruins of Arab and Roman irrigation works, of historical texts, of the continuity of cultivation methods and the cultivated plant species indicates that the climate is stable and has not become decidedly drier. Similarly, it was reported at the Jerusalem Desert Research symposium in 1953 that all the historical, botanical, and archeological evidence pointed to little change in climate during the last 80 years or so in Israel and India.

Tixeront has pointed out that drouths do occur and that we ought to become aware of their statistical probability; he has made a plea that we study all the climatic factors that may lead to the development of drouth periods as well as the factors that lead, conversely, to flood periods.

In Tunisia, information from historical and archeological sources has been used to good effect. The planting of olive trees at the same spacing as that used by the Romans in dry farming is successful today. So, too, wells, cisterns, and irrigation channels of Roman origin have given a guide to modern siting and use.

In semiarid and arid areas transpiration and evaporation—or to put them together as C. W. Thornthwaite, director of the Johns Hopkins University Laboratory of Climatology does under the term *evapotranspiration*—constitute the major factor in the recirculation of rainfall into the air, but it is notably difficult to measure evapotranspiration satisfactorily, because of differences in plant cover. It is becoming clearly evident that in some instances an increase in crops or pastures or tree cover may severely tax the capacity of groundwater supplies, and in general a balance has to be struck between the needs of crops and the water supply. Lysimeter experiments in South Africa indicate that only about 3 percent of rainfall goes lower than the root zone of veldt grasses. Phreatophytes, or plants like alfalfa that grow their roots down to the water table, are notable for their efficient transpiration; indeed I have on occasion recommended the use of alfalfa to drain waterlogged orchards in irrigated country. Worthless phreatophytes may waste millions of acre-feet of water in some arid lands.

In order to assess the water requirements of an area, wherever it may be, some way of measuring evaporation and transpiration must be used, yet strange though it may seem, we have not yet achieved exactitude even in reading evaporation pans. Thornthwaite, who has devoted his scientific life to the study of climate, has proposed a method for estimating the water need of a region so that it is possible, knowing the rainfall and the evapotranspiration, to determine how much additional water, if any, is needed by way of irrigation. He defines the total water need as the amount of water that will return to the atmosphere from a surface completely covered with vegetation when there is sufficient moisture in the soil for the full use of the vegetation at all times, and this he calls the *potential evapotranspiration*.

One way of determining evapotranspiration is by the "vapor transfer" method, which is based on the rate at which air near the ground is mixing with air above it at a given height and measuring the difference in water vapor content at the two levels. It is possible also to measure rainfall, the inflow of irrigation water, and the outflow water, and to regard the amount that does not run off as evapotranspired.

Latterly, specially designed soil tanks 4 square meters in area and 70 centimeters deep, in which plants can be grown under field conditions, have been set up in a number of places, each tank being surrounded by a large buffer area to insure greater accuracy in results, but not enough are yet in use to give the range of variation from one area to another. Meanwhile Thornthwaite and his colleagues have come to the conclusion that the computation of potential evapotranspiration for any place can be made from data on air temperature and latitude alone. With this information, it is possible to determine the water needs of an area and, as it were, to keep accounts whereby the most economical use may be made of irrigation water.

Having briefly referred to rainfall, using this as a general term, we may naturally consider what happens to the rainfall apart from evapotranspiration. Some infiltrates the soil and other layers and goes underground, where it may be stored or may move in suitable layers slowly toward the sea. The most generally used method of determining infiltration is to examine the data of the use and fall of water in wells, although today radioactive isotopes are available to make evident the movement of water through permeable strata. There are in the United States about 7000 observation wells, and approximately 5 percent of these have automatic recording equipment.

The examination of an area for underground water in the first place calls for geologic knowledge, and, properly, the use of geologists to make the survey with or without the aid of geophysics. By this means, exact records would be kept of all the wells or bores put down, the strata through which they went down, the quality and quantity of the water, and so on. Such a survey would enable us to make estimates of the total volume of the underground supply, of its area and depth in a confined source, or of its flow if unconfined, and the region of flow in the aquifer. It may be of interest that below the Nile there is an underground river about 560 miles long reaching from about 80 miles south of Luxor to about 70 miles north of Cairo. According to Mohamed El Sayed Ayoub, one-time inspector general for Nile control, the mean width of the stream is 10 kilometers, the strata of sand and gravel in which it flows ranges from 100 to 300 meters in depth and has a water storage capacity of nearly 500,000 million cubic meters, and the water takes nearly 100 years to arrive at the head of the delta. Each year 1400 million cubic meters are used for irrigation, another 1000 million cubic meters is planned to be used on 25,000 acres of a new irrigation project, about another 1000 million cubic meters are used by plants, and nearly 4000 million cubic meters flow into the delta unused.

This great aquifer under the Nile and the Nile itself receive their water from distant sources, but were they to rely on local rainfall for the infiltration and stream flow they would be dry for 6 months each year.

Another great arid area, the Thal desert area in western Pakistan, is being reclaimed; its reclamation illustrates regional organization of the order of the Tennessee Valley Authority in the United States. The area consists of a triangular area of nearly 5 million acres with a base of 65 miles along the Salt Range to the north and a length of about 175 miles to the apex at the south; it is located in the Punjab between the Indus, Jhelum, and Chenab rivers. Tradition, supported by geologic evidence, has it that the Indus formerly flowed down the middle of the area and deposited huge quantities of sand and silt; later it changed its course to the west. The superficial sand dunes arise from fine material blown from coastal and desert regions of Sind and Rajasthan.

The vegetation consists of low brush and scanty grass, on which camels browse. There are no indications of early occupation, such as are found in other parts, prior to the 14th century, when a few tanks of about an acre each were constructed by Emperor Sher Shah Suri.

The question of developing the Thal was first considered in 1870, but nothing was done until 1901 when a Colonization Bill authorized the construction of a canal to the Shamlat area. In 1936 the distribution of the waters of the Indus and its great tributaries was considered. Work on a Thal project was begun in 1939 but was held up because of the war. Existing channels were filled up with sand when the flood of refugees from India moved into Pakistan in 1947. Of these refugees, 250,000 are being settled in the Thal.

In 1949 the Thal Development Authority was established; it was to be responsible for the full development of an area of 834,500 acres; another area of 638,000 acres was to be developed by private enterprise with the assistance of the authority.

It was believed that the agricultural development of the area and the establishment of villages and small towns throughout the area needed the balance of industrial development, and so today there are sugar mills, cotton textile mills, a woolen mill, and a cement factory in the area. Some 640 villages have been established, each with 40 to 50 houses on a total of 100 acres; there is a green belt all around each village and a timber area of 50 acres alongside. Each settler is allowed 15 acres of land at a distance of not more than 1½ miles from his village, which he must cultivate satisfactorily.

The operational area of the Thal Development Authority originally covered the 1.5 million acres commandable by canal for irrigation, but in 1953 a wider scheme was examined for parts of the 3.5 million acres not commanded by canals. In certain belts masonry wells have for years been used to supply water for small holdings. The aquifer consists of sand layers with a water table at a depth of 40 to 60 feet in ample quantity; therefore a tube well scheme has been initiated. How successful this will be remains to be seen, because percolation is heavy and evaporation, with summer temperatures up to 120°F is high, but it is hoped that each well can irrigate 150 acres. Early last year Australia supplied tube wells to the Thal Development Authority under the Colombo Plan.

Before ending this very sketchy description of a brave project, I think it is safe to prophesy that in perhaps a decade there will be need to study a salt problem in parts of the Thal; the Food and Agriculture Organization of the United Nations is already at work in Pakistan on this problem in the Indus valley.

In arid and semiarid areas where the need for recharging the underground water is acute, there are often long periods without rain interspersed with short bursts of storm rains with extremely rapid runoff that carries astonishing quantities of

surface material of sizes ranging from silt particles to boulders. The storm waters are gone in a relatively short time, and the problem is to make good use of what are sometimes quite large supplies by spreading and slowing down the rush of waters by the use of dams and tanks, by selection of the site for percolation, and by other means.

It is impossible here to do more than indicate the complexity of the problems concerning water supplies. The U.S. Geological Survey has prepared a list of 30 ground-water problems that need research, and in arid areas the general problem of the development of water resources to the fullest economic capacity will always be a vital one.

I have referred to the possible development of salty conditions in some of the irrigated land under the supervision of the Thal Development Authority. Rainfall is relatively free from salts. When rainfall is adequate for agricultural production, excess soluble salts in the soil are leached away in the drainage water; but when rainfall is low, leaching is reduced and salt accumulation can occur. All irrigation waters contain salts dissolved from the rocks and soils through which the water moves. Some years ago C. S. Scofield, of the U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering, studied irrigated areas in the southwestern United States and described the salt balance as the relationship between the amount of salts being delivered in irrigation water and the amount removed from the area in drainage waters. This concept, backed by suitable methods for its application, may be valuable in preventing salting and in remedying existing salt conditions.

H. E. Hayward, director of the U.S. Salinity Laboratory at Riverside, Calif., has prepared a very comprehensive review for UNESCO of research on plant growth under saline conditions. In it he refers to the classification of saline and alkali soils, the quality of waters for irrigation, the physiological bases in plants for salt and alkali tolerance, and the effects on plant growth and on seed germination; he then succinctly reviews the position in Australia, India and Pakistan, South and Central America, and North America.

Because human, animal, and plant bodies are so largely made up of water, it is little wonder that the ability of man to live is dependent on his having plenty of good water. The same sort of relationship that obtains between population and food supply also obtains between population and water supply. It is little wonder, then, that men's minds turn to those seemingly inexhaustible supplies of water, the seas and oceans, and wish it were economically feasible to desalt sea water in immense quantities. On one occasion a sincere good wisher asked me whether it would be possible to construct a canal from the Mediterranean through the Negev desert to the Dead Sea and to use desalted sea water for irrigating the desert and raising the level of the Dead Sea waters with the drainage. The answer is that success in producing large quantities of fresh water economically from salt water is not just around the corner. There is no magic wand, but research is going on in many places, and there is little doubt that the day will come when in some arid areas it will be possible to provide desalted water at lower cost than, for example, water transmitted over great distances.

Everett Howe, of the University of California, has prepared for UNESCO an excellent summary of research on the utilization of saline water. Sheppard Powell, a member of the advisory group to the U.S. Secretary of the Interior on the Saline Water Conversion Program, has described the Saline Water Conversion Program. This program was established by the Congress of the United States; the research projects financed by grants-in-aid under this enactment are already highly productive, especially in assessing the merits and costs of producing fresh water from saline supplies. The Saline Water Conversion Program is scheduled to end in July 1957, but I am sure that many persons hope that it may be extended beyond that date.

Soils

The soil forms the base on which food production on the scale for world needs takes place. I do not propose to go into any detail about arid soils. Suffice to mention a few characteristics, such as their low content of organic matter and therefore their low content of nitrogen, the fact that they are more usually alkaline than acid and so may develop permeability problems with irrigation, and their sometimes rather high content of soluble salts. Despite these characteristics, crop yields under irrigation with suitable fertilizer treatments, can be remarkably high, and large-scale prosperous communities may be established, as has been the case in the United States and in Australia.

I cannot do better than quote Charles E. Kellogg, assistant administrator of the U.S. Soil Survey. In his summary to his introductory paper at the Jerusalem Desert Research symposium, he said:

> Several important areas of needed soil research are the following:
>
> 1) Morphological study of the soils of relatively unexplored regions and their classification as a basis for preliminary reconnaissance mapping and appraisal. Previous soil experience has been highly concentrated on alluvial soils and especially in areas

easily reached by existing transport. Soil scientists have had inadequate opportunities to make detailed studies of arid soils remote from present population centres. Even in places where water is scarce, principles of great fundamental value to our knowledge of the formation and development of arid soils can be learned—principles important generally and to the stabilization and use of arid soils for grazing even though they cannot be irrigated.

2) Relation of soil permeability to drainage and salt removal. We need to know more precisely the lower limit of permeability, especially in subsoils and substrata, for satisfactory management with different kinds and amounts of irrigation water, the factors that control the permeability, and how permeability may be modified by chemical treatments, growing plants, and water management.

3) Development of structure and water-holding capacity in arid sandy soils through use of better adapted green-manuring crops, organic soil conditioners, or in other ways.

4) Better methods are needed for appraising the salt balance in whole watersheds where irrigation water is taken from streams and the drainage water is returned into the streams to be used again for irrigation at one or more lower levels.

5) More precise studies are needed of the soil properties that lead to chlorosis in plants and of ways to modify them.

6) The reasonable alternative combinations of plant nutrients, water supply, plant spacing, and cropping systems need to be tested in order to find the most nearly optimum ones for each kind of soil in terms of harvest, sets of practices, and the long-time effects on soil productivity. The results must be set forth in the specific terms required for calculating costs and input-output ratios needed in farm budgeting.

Plants

In the paragraphs on climate, reference was made to the fact that there is little evidence of any marked climatic change for the worse since man used or misused the land for living. The effectiveness of rainfall has, however, been seriously reduced by man's overuse of plow, axe, and grazing animal, particularly the goat. Marginal areas have become man-made desert areas, and it is in this sense that the desert is advancing. In any attempt to reestablish marginal areas for better production and living conditions, it is necessary to survey and map the existing plant cover—whether natural or cultivated—and land use—as is being done or planned by the U.N. Food and Agriculture Organization in cooperation with national authorities.

The main task is to attempt the regeneration of a better plant cover and to do this while the population is engaged in gaining a living from the area. It is essential to have as guides in this work enclosed or protected areas that are ungrazed, in order to study such natural regeneration as may occur; indeed, sometimes the results may be startling. There is one thing that we cannot do, and that is to take over procedures from one area in one part of the world and at once begin to apply them elsewhere in the expectation that they will be successful. Much experimentation is needed in selecting suitable plants and in getting them seeded, germinated, and growing in these very old environments.

It is dangerous to disturb the land surface more than is necessary, even with good intent, because of the possibility of soil removal or seedling sacrification by the sand-loaded winds that blow in the hot season. I have seen this in the Thal Desert of Pakistan, where we are making trials with a number of plants. It seems to me that the provision of some shelter from these searing winds is essential; this can begin around nursery areas and in strips suitably placed across the prevailing winds. The limitless horizons of the desert are very interesting to write about, but they are not good for proper land care.

I come from a land where it has been necessary to introduce and establish every kind of plant food that one can think of for man and his animals, with the exception of the native grasses and top-feed, dry-climate trees such as mulga (genus *Acacia*). We have successfully introduced every kind of fruit and vegetable that can be grown anywhere, and we are still testing many grasses and legumes. The same things have been done in the United States, where, I think, trial introductions from all over the world total more than 65,000. Outstanding with us has been the success of the establishment of subterranean clover, which has meant untold millions to the sheep men of southern Australia. ***Phalaris tuberosa*** and rye grasses (***Lolium spp.***) in the south, *Cenchrus spp.* in the west, and Rhodes grass in Queensland are other illustrations. Both the United States and Australia use alfalfa, called lucerne in Australia. The American name is nearer the Arabic, which means "the good plant." I refer to this to illustrate the possibilities of plant exploration for grasses and legumes, particularly in old arid areas. There is much yet to be done in this field.

In the detailed studies that are essential with respect to any of these introductions there will be plenty of scope for selection and genetical studies of those that show promise of establishment. In Australia now, for example, are a number of established strains of subclover; Americans may find that *Trifolium hirtum*, a native of Turkey that has now been established in California, will develop ecotypes.

It is obviously necessary to learn what are the physiological factors that enable desert and near-desert plants to survive long periods with limited water supply under conditions of excessive insolation, very high day temperatures, and low night temperatures.

Animals

Omar Draz, director of the Desert Range Development Project in Egypt, has also referred to the need for a thorough understanding of the ecological, genetical, and physiological bases that will permit the selection of plants and animals most suited to arid conditions. He has also drawn attention to the importance in animals of heat tolerance and heat dissipation, about which much is still to be learned. He has stressed the idea that it is shortsighted to look down on local breeds that have become adapted to the conditions of living in the environment.

Man

Whatever research work is done in any or all of the fields we have so far considered, the end result should be for the benefit of man, and it is appropriate therefore to think at this stage about man himself, his well-being and living conditions. One striking feature of man in the desert is his nomadism. Although it may always be that some movement of flocks must occur to and from grazing areas, it does not follow that the shepherds must remain nomads. It is unnecessary to do more than point out how very different are the lives of men, women, and children under nomadic conditions from the lives of those who do not live under nomadic conditions. Any changes in modes of living must mean great social adjustments for those people.

Ladell, director of the Hot Climate Physiological Research Unit in Nigeria, in discussing the influence of environment in arid regions, has pointed out the wide range in temperature that man has to live under—for example, at Basra the mean monthly minimum varies from freezing to 83°F and the mean monthly maximum from 67° to 109°F. Under these conditions there are little cloud cover and scanty vegetative cover and the ground radiates heat, and dust-laden air radiates still more heat. With wind in addition, water loss from the body may proceed faster than is physiologically desirable. Ladell refers to heat acclimatization, by which is meant the physiological changes resulting in an improvement in work following exposure in a hot environment, and he considers that man can live under conditions more severe than those that occur in the hottest parts of the world. Protection from direct solar radiation is desirable in the form of a light broad-brimmed hat, or, on a tractor, a canopy over the driving seat.

Good housing is essential—cool by day and such as to give adequate protection at night—and in this respect the thick-walled, small-windowed, pisé houses of the Near East, Pakistan, and India are types.

Water is the essence of life, and it seems a pity that because of religious beliefs or tradition desert dwellers do not take to the use of galvanized iron tanks to store roof water.

Desert dwellers may suffer from prickly heat and from malnutrition and vitamin-A deficiency, which leads to slow healing of wounds.

Power Sources

We who live in comfort find it hard to realize what life is like without electricity or gas, without water in pipes, without refrigeration and radios, without air conditioning in buildings, without good roads and fast cars, and so forth. But many thousands live where hydroelectric power is not available and where fossil fuels like coal and oil cannot be used. So we turn to such sources of power as wind and sun.

Successful wind-driven generators up to 70-kilowatt capacity are operating in Denmark, and two prototypes of 100-kilowatt capacity are functioning in the United Kingdom. Much thought is being given to automatic regulation in variable winds in order to make the fullest use of wind power. It is extremely important to choose the right site for a windmill.

The use of wind power to pump water either directly or through the use of electricity should result in saving bullock power and thereby acreage for human food.

Solar energy has already been put to work for cooking and heating water. Equipment was demonstrated in action at New Delhi, India, in November 1954. The problem is to reduce the cost to within the means of the average Indian. In California, hot-water heaters have been installed on roofs with insulated hot-water storage tanks.

Considerable thought and experimentation is being devoted to the possibility of developing a solar engine. C. G. Abbot, of the Smithsonian Institution, has long pioneered in this field.

Conclusion

I have merely touched on a few points in a few of the many fields of research that must be pursued if we are to achieve the results we wish for. In any

scientific work it is first essential to survey the field. In this case it is a survey of several fields, and therefore it is a highly complex operation calling for teamwork of the highest order. I do not decry individual effort, for indeed some of the great contributions to knowledge have been made by the Newtons and Einsteins. But in considering the challenge of arid lands, it is impossible to avoid the inference that in this research we must have teamwork; that teamwork should be between individuals, between universities and research institutions, and between peoples—in other words between United Nations organizations.

Particularly does it seem appropriate that we who belong to those sections of mankind that enjoy the highest standards of living should see a plain duty to help in every way possible to benefit the less well-off sections of mankind.

Irrigation, Flood Control, Power Production

The cover this month is a photograph of the Hungry Horse Dam, which is located on the South Fork of the Flathead River in Montana. This aerial oblique view, photographed by A. E. McCloud, is looking upstream and shows the power plant and reservoir area as well as the dam. Hungry Horse Dam, completed in 1952, is 564 feet high and 2115 feet long at the crest and contains more than 3 million cubic yards of concrete. The dam is 39 feet wide at the top and 330 feet wide at the maximum part of its base. The power plant houses four generator units with a combined capacity of 285,000 kilowatts. The reservoir has a surface area of 22,500 acres and a maximum depth of 500 feet. It is 34 miles long and 3½ miles wide at its widest part. The capacity of the reservoir is 3,468,000 acre-feet.

Problems in Zoological Polymorphism

JOHN M. BURNS

This article was originally written as a term paper by John M. Burns during his junior year at Johns Hopkins University, for a course in organic evolution, and was revised by him during his senior year. Mr. Burns is now a graduate student in the department of zoology at the University of California, where he expects to pursue work in the fields of animal ecology and evolution. This is his first scientific publication.

TOO much useless argument has raged and will continue to rage over questions that involve no basic disagreement between the contesting individuals or factions but rather a misunderstanding stemming from semantic difficulties. A language necessarily is modified with time. That part of language known as scientific terminology is like an x-rayed *Drosophila* in that a greater number of new words crop up on which selection can act, although these words, unlike the analogous mutations, contain a somewhat smaller lot of detrimentals. Just as chromosomal aberrations may induce position effects, so the shuffling and bringing together of preexisting words into new combinations will alter meaning.

A desire to be original, a drive for individuality, may seek expression in other ways than the creation of new words or the recombination of old ones. The poet is not the only man for whom familiar, well-established words assume restricted private meanings or shades of meaning; the scientist may form subjective definitions, even for those words that figure in his technical terminology. Confusion will result; for, although it is the nature of good poetry to be plastic, to be open to more than one line of interpretation, to say more than the sum of all the single interwoven elements, a scientific work should be objective and unequivocal, in language as in experiment, observation, and reasoning. The rapidly evolving terminology that harries any hypertrophic field of biology such as genetics inevitably creates perplexities.

As originally conceived, the word *polymorphism* referred (in its biological sense) to the existence of two or more varieties or phases of an animal or plant species. Thus it meant, quite literally, "many forms," and these forms were usually strikingly different. But the term has been used loosely, so that polymorphism has come to be applied to forms that are hereditary and to those that are environmentally determined, genotypic and phenotypic varieties; to forms coexisting at any given moment of time and those that are successional, as seen in snapshots and in motion pictures, respectively; and to forms coexisting in space and those that are spatially removed from one another. The difficulties inherent in such inconsistent usage have not been surmounted; and in the field of genetics the word has been even more broadly applied. Before launching into a discussion of some modern genetic aspects of polymorphism, it may be well to illustrate the general phenomenon and the variety of examples to which it has been applied.

Among the colonial coelenterates of the class Hydrozoa, variations on both the polyp and the medusa themes provide classic examples of polymorphism. In contrast to *Hydra,* in which all the essential functions of life are carried on within a single polyp, *Hydractinia* has polyps specialized for feeding, defense, and reproduction; and *Physalia pelagica,* the Portuguese man-of-war, has, in addition, gas-filled polyps that serve as a float. In both genera the defensive or fighting polyps lack the mouth characteristic of the feeding polyps and bear nematocysts. In order to maintain the view that polymorphism is exhibited here, it is necessary to consider the polyps as individuals composing a colony and not to consider an entire colony as a single organism, although it is true that the polyps have lost their independence and function in a manner similar to organs or organ systems by means of a division of labor. Sexual and nonsexual medusae occur in some hydrozoans; indeed, the very alternation of generations may be taken to be a kind of polymorphism.

The color phases of some North American animals furnish obvious examples of polymorphism. In the tiger swallowtail (*Papilio glaucus*) that ranges from Canada south through Florida and Texas, the males are always yellow and black, while the females are dimorphic: one type rather closely resembles the male; the other is dark brown. The brown females are rare or absent in the North and are absent in southern Florida; but in some localities in the South they comprise as much as 50 percent of the female population, gradually becom-

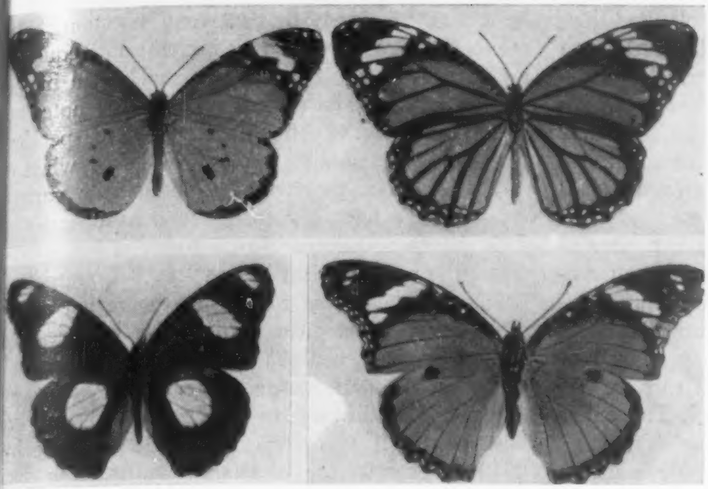
ing less common northward (*1*). The red-backed salamander (*Plethodon cinereus*), a species often discovered beneath logs and stones in wooded areas of northeastern North America, exists in two color phases: red-backed and dark gray- or black-backed. In some regions the two phases occur in equal numbers, while in others the red or dark phase may predominate. In the timber or banded rattlesnake (*Crotalus horridus*), frequently encountered in the mountains of the eastern United States, the dark V-shaped crossbands on the back and sides interrupt a ground color that may be yellow or brown-black. The red-brown and the gray color phases of the widespread screech owl (*Otus asio*) are not sex-controlled and therefore exhibit a phenomenon distinct from the sexual dimorphism in plumage commonly found in birds. Among mammals, the black bear (*Ursus americanus*), erratically distributed over a large part of North America, is black in the East, while in the West it is represented by both cinnamon and black phases. In addition, there is an almost white phase on Gribble Island, British Columbia, as well as a gray-blue phase near Yakutat Bay, Alaska.

In modern studies of polymorphism the name of E. B. Ford is outstanding. He has kept in close contact with the subject over the past two decades, contributing original data, interpreting those of others as well as his own, and periodically summarizing various aspects of the problem. Ford (*2*) has defined polymorphism as "the occurrence together in the same habitat of two or more distinct forms of a species in such proportions that the rarest of them cannot be maintained by recurrent mutation." He has qualified this definition by pointing out that it includes neither seasonal and geographic variation nor continuous variation. Continuous variation, which may be "usefully defined as variation at least no greater than that which, on the average, separates parent from offspring" (*3*), is represented by a normal, bell-shaped, frequency distribution curve of variability, while the "distinct forms" of polymorphism result in curves that, if not separate, will at least be bimodal or multimodal (*2, 4*).

There is an important distinction between geographic variation and polymorphism, although both terms involve the existence of more than one "normal" form within a single species. Often a species is not uniformly distributed over its range. It tends to be broken up into many populations that, if discontinuous, generally undergo differentiation that may, over a sufficiently long period of time, give rise to subspecies and new species. However, even more or less continuous populations, especially those that extend over a large area, will encounter different environmental conditions; and through natural selection each population will gravitate toward a maximum degree of adaptation to its local habitat, so that, despite interbreeding between adjacent populations, there develops internal differentiation within the species as a whole. Particularly in the case of species characterized by low mobility, no direct gene-flow can take place between spatially removed populations. Although internal geographic differentation is frequently random, it may follow a pattern. Thus in northern and southern populations of a species, nonidentical genetic combinations may be built up that grade into each other through a continuous series of intermediate populations. A gradation of genetically determined characters over a geographic range produces a cline. The diverse forms found in a cline do not coexist in the same locality and therefore do not constitute polymorphism, in which the two or more forms must occur together.

In regions of abrupt topographic and environmental change, gene-flow between adjacent populations may be impeded to such an extent that an evenly graded cline no longer exists. If the clinal gradient of a particular species is relatively steep in some regions, taxonomists may find it convenient to recognize subspecies, whose ranges will overlap only in these narrow zones of abrupt change. Within these zones, the interbreeding that does take place between the different subspecies will not produce polymorphism, because the distinct forms will lose their identity in a multiplicity of intermediate varieties—that is, continuous variation will be the result.

Clinal and polymorphic variation may, nevertheless, be interrelated. Although intraspecific variation of a purely clinal nature does not constitute polymorphism, a polymorphic species is quite capable of forming a cline. Consider, as a simple example, a dimorphic species whose alternative forms are controlled by a single pair of alleles. One allele produces a dark form that is best adapted to cool temperatures; the other results in a light form for which warmer temperatures are optimal. If the range of this species embraces considerable variation in latitude (or altitude), a graded frequency of the two forms will be the consequence. In the northernmost populations all individuals will be dark. Farther south, the light form will begin to appear, at first in limited numbers; but the percentage of light individuals will increase from one population to the next, until at the opposite extreme of the range, the populations will again be monomorphic, consisting of only the light form. A more complex situation sometimes arises, involving both continuous gradation and a poly-



Mimicry of a danaid (milkweed) butterfly. Top (left) male *Danaus chrysippus*. Bottom (left) male *Hypolimnas misippus*; (right) female *Hypolimnas misippus*. The female of the second species, instead of resembling the male of its own species, is very similar to *Danaus chrysippus*, which belongs to a different family. (Another species of milkweed butterfly is shown at the top right.) [From Punnett, *Mimicry in Butterflies*, Cambridge University Press, 1915]

morph-ratio gradient. Polymorphic species are known in which not only the relative proportions of the various forms exhibit graded changes from one locality to another but also the forms themselves change gradually from one region to the next in regard to various genetically determined characters.

Ford recognizes two major types of genetic polymorphism: transient and balanced. In the former a beneficial gene is in the act of establishing itself in a population, while in the latter it has spread to some frequency at which it is checked by an opposed selection pressure. The distinction between the two types is not clear-cut; in some instances it is difficult or impossible to tell whether a gene is merely fluctuating about a fixed level or is replacing an allele in a population, for this replacement process may require a long period of time, especially if the selective advantage of the favored gene is quite small. The question arises, why has not a favorable gene long since become incorporated into the genotype of the organism? Such would surely be the case if the environment were stable; but inasmuch as it undergoes evolution with time, a recurrent mutation (or a mutation carried in the "hidden variability" of the organism) which has long interacted harmfully with the environment, may, under changed conditions, possess a selective advantage that would enable it gradually to spread and perhaps to oust what was formerly the "normal" allele. As long as both alleles are numerous, the population can be considered polymorphic. If the "upstart" allele continues to advance unopposed, it will eventually establish itself as the "normal" one, relegating its predecessor to the status of a rare allele maintained only by recurrent mutation. The population will once again be uniform relative to this pair of alleles, and the polymorphism created by the process will have been temporary (*5*).

Since transient polymorphism is generally associated with a modification of the environment or with the colonization of a new habitat by an organism, Ford (*2*) suggests that the phenomenon should be particularly prevalent today because of the great environmental changes wrought by mankind. Despite the difficulty of ascertaining whether a variety is spreading or whether an equilibrium has been attained between two (or more) forms, some situations may reasonably be attributed to transient polymorphism.

For example, the hamster, *Cricetus cricetus*, typically inhabits the dry zone of the Russian steppes. Normally it is gray, although a rare melanic form occurs owing to an autosomal recessive gene. In the late 18th century the naturalist-geographer Lepekhin noted that a population composed largely of the melanic form inhabited a small area near the foothills of the Urals. Since then the black hamster has steadily spread to the west along the northern limit of the species' range in the moister wood-steppe subzone, so that it is now common in the area of the Dnieper River. The melanic form seems to possess some advantage in the moist wood-steppe subzone that it lacks in the dry steppe zone, an advantage that may be the result of physiological differences associated with the production of the black color (*2, 4*). Ford conjectures that since human interference in this area is negligible, and since there must be a fair number of heterozygotes in the population (because of the occasional presence of the homozygous recessive melanics), "it is not clear . . . why the variety did not spread at a much earlier date, unless we may

invoke the onset by natural means of conditions favourable to it." Polymorphism has been transient in those areas in which the black form has completely replaced the gray form. But in the transition territory between the two ecological zones, where neither variety would possess a selective advantage over the other, both black and gray hamsters should occur in a balanced polymorphism.

Other cases can be cited in which the process of spread, although not actually witnessed, can reasonably be inferred. In the brush opossum, *Trichosurus vulpecula,* of Australia and Tasmania there is a melanic variety (probably produced by an autosomal recessive gene) that is rare on the mainland but common on the island. The entire population of the northwest corner of Tasmania consists of the black form, whose frequency in the population declines to about 25% on the island's east coast. The view that the melanic appeared in the northwest and is in the act of spreading through the population is strengthened by the fact that the partial barrier imposed by the narrow-necked Tasman Peninsula has resulted in a relatively lower frequency of melanics on the peninsula than in the adjacent region of the main island. "It is interesting to note that Tasmania is cooler and moister than Australia, so that the similarity to the case of the black hamster is very close" (*4*).

The simplex condition of the teeth in the field vole, *Microtus arvalis,* of north-central Germany is found in approximately 90% of the individuals in Schleswig-Holstein and Mecklenburg and decreases in frequency in a clinal manner to the east, south, and west of this center. The mountains of central Germany have completely blocked the spread of this character, and some of the large German rivers have hindered it. Although this is apparently another instance of transient polymorphism, a state of equilibrium may already have been reached; or it may yet be reached before the simplex condition becomes universal (*2, 4*).

A striking example of transient polymorphism is industrial melanism, which Ford calls "the most considerable evolutionary change which has ever actually been witnessed." This phenomenon has been summarized briefly by Dobzhansky (*6*), and more extensively by Huxley (*4*) and particularly Ford (*2, 3, 5, 7–10*). In several industrial areas, chiefly in England and in continental Europe, all or almost all of the population of various species of moths (in most cases of the family Geometridae) has become black over a relatively short period of time. Melanic varieties occur as rare aberrations throughout the ranges of these species. In heavily industrialized regions the dark varieties of some species became too common in the population to be explained merely by recurrent mutation. Subsequently they were seen to increase in frequency and finally to supplant the "normal" form in the polluted areas. The phenomen was first noted in *Biston betularia,* which is normally white, speckled with black, resembling a patch of lichen when it is at rest on a tree trunk. The melanic variety *carbonaria,* originally recorded near Manchester in 1850, afterward spread, until today it has superseded the normal form in the "Black Country" of northern England as well as in the region about Manchester. This pattern of events is typical of several species. Ford (*2*) cites the especially rapid spread of the dark variety *albigensis* of *Tethea or* (family Thyatiridae) in the area of Hamburg, Germany: "It was very rare in 1904, while by 1910–11 over 90% of the larvae collected in that area produced it." Ford believes that incipient industrial melanism would be revealed, by careful study, in a great many species in industrial areas.

Although the species showing industrial melanism fall into many different genera, they all conceal themselves in the same way, by relying on cryptic coloration rather than crawling into cracks and crevices. Furthermore, it has been shown that in each case the melanic forms are caused by simple dominant or semidominant alleles and are more viable than the normal form. Ford (*7*) himself has demonstrated the superior viability of melanics over normals in *Cleora repandata.* Some workers have suggested that industrial melanism is a result of the selection of dark varieties in manufacturing areas, where they would match their blackened backgrounds better than the normals, which conversely would be favored in unpolluted country. Harrison has tried to prove that the mutation to melanism is caused by the presence of lead and manganese salts in soot on the leaves eaten by the caterpillars in industrial areas. Both views, particularly the latter, are open to serious criticism (*2, 7, 9, 10*). Ford (*3*) advanced a hypothesis that he has strengthened by experimental work on *Cleora repandata* (*7*) and reemphasized in subsequent publications (*2*):

> All genetic factors which improve the viability of the organism must have spread through the population, displacing their allelomorphs, and become incorporated in the gene complex of the species, except those which in addition carry with them some disadvantage sufficient to outweigh the superior hardiness which they confer. Among these latter we may reasonably include any that are responsible for such an excess of melanin production as to destroy the cryptic pattern of the insect, upon which its safety depends. However, black colouring will not be such a handicap, perhaps even an asset, in industrial districts, and this for

Polymorphism and mimicry among swallowtail butterflies. The species *Papilio polytes* has three types of females, one of which resembles the male, while the two others mimic different species. (1) Male *P. polytes*, left side; (1*a*) underside of hindwing. (2, 2*a*) Female *P. polytes* var. *cyrus*, resembling male of the same species. (3, 3*a*) *P. polytes* female var. *polytes*, which resembles 5 and 5*a*, *Polydorus aristolochiae*. (4, 4*a*) *Polydorus polytes* female var. *romulus*, resembling 6 and 6*a*, *P. hector*. All these swallowtail butterflies are from Ceylon, where they are abundant. The gray-looking spots on forms 3 to 6 are actually pink to vermilion in color; there is little or no red on the wings of *P. polytes* males, or females of var. *cyrus*. The models (Polydorus) belong to a group of distasteful papilionids. [From Punnett, *Mimicry in Butterflies*]

two reasons. (1) It will tend to match the smoke-grimed tree-trunks and fences. (2) There may well be fewer predators in such places, so that the selection pressure in favour of the correct colouring will be less intense. [Huxley (*4*) has further suggested that "in the chemically unfavourable environment of industrialism, the greater hardiness of melanics would have an increased advantage."] Here then the species may at last be able to avail itself of those genes which confer greater viability, even though they may involve an excessive formation of melanin.

It will be noticed that, on this theory, melanics might be successful even if the disadvantage due to their colour is merely reduced though still present, and that appearance is not the quality for which they are selected. Also that they are not due to the induction of mutation; for I assume that these species have constantly had experience of the genes responsible for industrial melanism, but hitherto they have not been able to use them. Of this, indeed, we have good evidence, and it should have been apparent long ago that industrial conditions are not necessary for the *production* but for the *spread* of the black varieties. For example, the black form (*cornelseni* P. Hoff.) of *Ectropis extersaria* Hb. is, in fact, known in England, but only as a rare variety; it has never established itself here since the distribution of the species does not include manufacturing areas; but it does so in Germany, where *cornelseni* has proved a success and become an industrial melanic.

Industrial melanism has been observed also in the larvae of some species of moths. The black caterpillars produce normal imagines, even in species in which adult melanics are known. Ford (*3*) has pointed out that it is not surprising "that the characters of the larva and the imago are generally determined independently. On evolutionary grounds, any necessary association between them would usually be harmful; for even variation on

similar lines would generally have a very different adaptive value in these instars," whose ecology is so different.

Populations composed of melanic adult moths have been found in several English woodlands in regions unaffected by industry. Calling attention to the very delicate selective balance between the cryptically colored but less viable normal form and the hardier but noncryptically colored melanic form, Ford (*2, 10*) attributes these local melanic populations to a shift in the balance (which usually is inclined toward the normals) in favor of the melanics, owing to local environmental changes that alter ecological relationships.

The second major type of genetic polymorphism —balanced polymorphism—results when the selective advantages of two or more forms counteract one another so that a stable equilibrium is maintained. For example, the African nymphalid butterfly ***Hypolimnas misippus*** is a Batesian mimic in which the females are dimorphic and copy two subspecies of a danaid butterfly that is distasteful to predators, while the males are monomorphic, nonmimetic, and quite unlike their mates. The two female forms, determined by a single pair of autosomal, sex-controlled alleles, one of which is dominant over the other, are kept in an equilibrium that is influenced by the numbers of the model. The assumption of various mimetic forms by an unprotected species permits the species greatly to increase its numbers with comparative impunity; but as soon as any mimetic form becomes too numerous relative to its model, the protection gained through the mimicry is lost. What was an advantage is converted into a disadvantage, and selection begins to operate against the overabundant form. The results of breeding experiments imply that this ecological check on the proportions of the mimetic forms is often supplemented by a genetic control; thus in ***Hypolimnas misippus,*** homozygous dominant females appear to be relatively less fertile or viable.

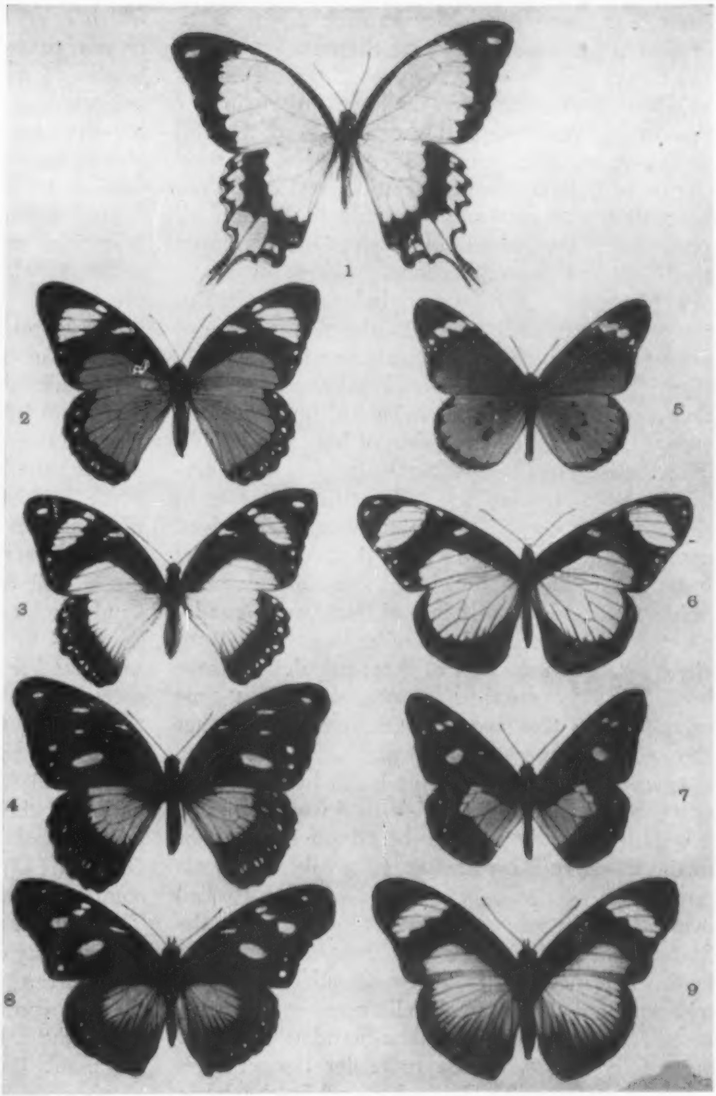
In a closely related species, ***Hypolimnas dubius,*** also from Africa, one pair of autosomal alleles controls a mimetic dimorphism that affects both sexes. Each of the two forms undergoes remarkable geographic variation: one phase copies different species in different parts of its range; the other mimics two geographic races of a single model.

The sex-controlled trimorphism of the oriental swallowtail butterfly ***Papilio polytes*** is due to the interaction of two pairs of alleles. While all males are monomorphic and nonmimetic, among the females the form *cyrus* (***R-aa*** or *rraa*) is similar to the male; a second form *polytes* (*rrA-*) mimics ***Polydorus aristolochiae***; and a third form *romulus* (*R-A-*) mimics *Polydorus hector.* As in the case of *Hypolimnas misippus,* there is some indication that homozygous dominant females are less fertile than others. Where the range of ***Papilio polytes*** exceeds that of *Polydorus hector,* only the *cyrus* and *polytes* females occur (*10*).

Although the nonmimetic individuals of a mimetic species generally reflect the characteristics of the genus to which the species belongs, the mimetic types may be totally different with regard to form, pattern, coloration, and even habits, closely resembling, in these respects, their models. One of the most extraordinary features of mimetic polymorphism is the fact that such disparate forms can be controlled by but a single pair, or at most two interacting pairs, of alleles, in the manner previously described. Attempts to account for the origin of this simple genetic switch-mechanism that effects so profound a change have produced two schools of thought.

Fisher and Ford, reasoning on the basis of Fisher's theory of dominance modification (the origin of dominance by gradual selection of modifiers in the heterozygote), have offered the following explanation. Any mutation that appears in an unprotected species and chances to give it some slight resemblance to a protected species will possess a selective advantage relative to its allele, so that selection pressure will gradually increase the frequency of the mutant allele at the expense of the "normal" one, until an equilibrium condition is attained. In addition, the phenotypic effects of the mutant gene will be altered with time, for selection will also favor all modifiers in the gene-complex of the species and all new mutations that, acting in conjunction with the mutant gene, tend to bring about a closer resemblance to the model. Thus, while the expression of the mutant gene will gradually be improved by selection, the gene itself will remain unchanged, serving as a switch that controls alternative forms whose frequencies in the population will be contingent upon ecological factors such as the population density of the model, as explained in foregoing paragraphs.

In opposition to this view, Goldschmidt has advanced a theory that is an outgrowth of an idea originally proposed by Punnett in 1915: namely, the sudden appearance of a fully mimetic form by a single mutational step. Goldschmidt (*11*) cites a number of features that govern the patterning process in the lepidopteran wing, particularly "a special pattern of crossbands which basically is more or less alike in all groups, though it may be suppressed, enriched, or distorted in individual groups. . . . It is remarkable how a great many different patterns may be derived from this basic one by



Female swallowtail butterflies (papilionids) and brush footed butterflies (nymphalids) that mimic milkweed butterflies (danaids) whose acrid body juices discourage attack from predators. Of the many types of mimetic and nonmimetic females that occur in the species *Papilio dardanus*, three mimetic types are figured, together with their respective, quite unrelated, models. Two of the latter species are also copied by a nymphalid, *Hypolimnas dubius*. (1) *P. dardanus* male. (2) *P. dardanus* female var. *trophonius*, a mimic of 5, *Danaus chrysippus*. (3) *P. dardanus* female var. *hippocoon*, a mimic of 6, *Amauris niavius*. (4) *P. dardanus* female, var. *cenea*, a mimic of 7, *Amauris echeria*. (8) *Hypolimnas dubius* var. *mima*, another mimic of *A. echeria*. (9) *Hypolimnas dubius* var. *wahlbergi*, another mimic of *A. niavius*. All forms are African. [From Punnett, *Mimicry in Butterflies*]

splitting, fusion, disappearance, shortening, simplification or complication, and shifting of the main elements, processes in which the different systems [of this basic pattern] . . . tend to vary independently." Numerous mutations alter this patterning process and the wing shape to a greater or lesser degree. Moreover, since it is known that environmental factors produce seasonal variation in pattern, color, and size of the wings, and that laboratory experiments involving temperature shocks and hormone treatments effect similar marked changes, it is not difficult to conceive of single mutations that, acting in conjunction with developmental processes, particularly at an early stage, may bring about radical morphological (and possibly even behavioristic) changes in one step. Those macromutations that crop up in an unprotected species and cause it to resemble a protected one will be preserved and favored by selection until their frequency in the population rises to a much higher level (*11, 12*).

The whole complex problem of the evolution of mimetic polymorphism has been very incompletely studied. To seek one explanation that will cover all cases is futile. But of the two theories just discussed, although neither seems thoroughly satisfactory, that of Goldschmidt reflects the more promising approach. Goldschmidt, against the broad background of his classic work on sex determination in *Lymantria*, has combined genetics,

embryology, and physiology in such a way as to achieve a dynamic outlook on the entire problem. His theory appears to be more plastic, more adaptable to individual cases, in the long run far simpler than that advocated by Fisher and Ford. During recent years, Ford and his coworkers, in their studies of polymorphism, variation, and evolution, have shown themselves too ready to explain all phenomena by the adaptive selection of minute modifiers and micromutations.

Polymorphism is frequently balanced because of the genetic barrier provided by the phenomenon of heterosis, in which the heterozygote is adaptively superior to both homozygotes. Obviously a population cannot be composed entirely of heterozygotes, except through the mechanism of balanced lethals. The homozygotes will occur in frequencies determined by their viability and fertility relative to the heterozygote and to one another in any given environment. One of the most thoroughly studied instances of such heterosis involves chromosomal polymorphism in populations of *Drosophila pseudoobscura* in western North America. The third chromosomes in the flies of these populations have been found to contain a number of distinct gene arrangements that have arisen from one another through overlapping inversions.

Inversion heterozygotes produced by combining any two gene arrangements derived from the same population usually prove to be adaptively superior to the inversion homozygotes. In a wild California population of *Drosophila pseudoobscura* studied over a period of years, the frequencies of the Standard and the Chiricahua gene arrangements in the chromosome pool were found to fluctuate with seasonal change in a cyclic manner. The gene complex locked together by the Standard inversion apparently adapts the fly to cooler temperatures better than does the Chiricahua, while the latter is in turn superior at warmer temperatures, thus permitting the fly a high degree of adaptation to its environment during different seasons. A similar study in the Sierra Nevada has shown the Arrowhead inversion to be adaptively superior to the Standard inversion at high altitudes and the reverse to be true at lower altitudes. The heterotic heterozygote Standard/Chiricahua (or Standard/Arrowhead) guarantees the availability to the fly population of both chromosomal types throughout the year (or at all elevations), so that natural selection eliminates neither type "but conduces the population towards the equilibrium point which is adaptively most favorable in a given environment" (*6*).

Timoféeff-Ressovsky has described an analogous situation in the ladybird beetle *Adalia bipunctata*, which exists in a number of light and dark color phases controlled by one or two allelic series. Studies of wild populations near Berlin, Germany, indicate that the dark forms are more viable during the summer, while the light forms are better able to survive the winter (*6*). Ford (*2*) draws attention to the balanced polymorphism demonstrated by the laboratory population studies of L'Héritier and Teissier on *Drosophila melanogaster*, in which homozygous wild-type individuals prove to be superior in viability to ebony/ebony homozygotes, and the ebony/+ heterozygotes more viable than either.

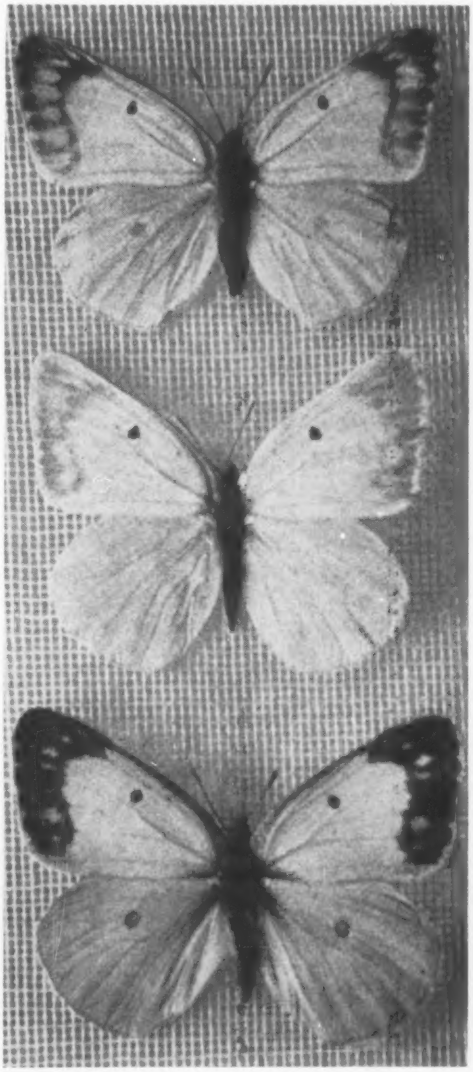
Nonmimetic as well as mimetic balanced polymorphism has been analyzed genetically in butterflies. In one of the European fritillaries, *Argynnis paphia*, the males are always rich fulvous with black markings, while the females are dimorphic: the common form *paphia* is similar to the male; the rarer, sporadically distributed variety *valezina* has a dull green ground color. Investigations by Goldschmidt and Fischer have shown that *valezina* is caused by a single dominant gene that is autosomal and sex-controlled and closely linked with a recessive lethal in most of the range of this species. Since the homozygous dominant does not survive, *valezina* is usually rare, occupying about 5 to 15 percent of the female population at most. Elimination of the lethal in the laboratory enabled the breeding of a homozygous *valezina* strain (*3*). Gerould (*13*) has described a parallel case in the common sulfur, *Colias philodice*, of North America. The males are always yellow, bordered with black; the majority of the females resemble the male, but in some the yellow is replaced by white. As before, the less common female form turned out to be under the control of an autosomal, sex-controlled dominant, linked with a recessive lethal. Gerould obtained pure white stocks by crossing over. Ford (*2*) offers the following comments:

> It is apparent that the 'recessive lethal,' which reacts fatally with the pale forms of *Colias* and the *valezina* form of *Argynnis paphia* must, in other circumstances, be of some advantage to the species, otherwise it could not be widespread in them (it is not of course suggested that the lethal is the same gene in all). Similarly, these rarer dominant forms must themselves be at some advantage in the heterozygous phase, otherwise they would not have spread until they occupy even as much as 2% of the population. We have here a curious balance of selective advantages of a type frequently encountered in polymorphism. It would at first seem remarkable that the viability of the homozygous dominants when interacting with the 'recessive lethal' has not been improved by selection so as to permit the uninterrupted spread of the rarer but

advantageous polymorphic form. It is not possible to explain this in the present state of our knowledge. It may, however, be conjectured that to modify favourably the response of the organism to the rare homozygote might endanger the advantage which the recessive lethal must undoubtedly confer (on account of its frequency in the population). Indeed, we may assume that all advantageous genes which can be spread even as homozygotes, without interfering seriously with the existing genetic adjustments, have in fact been incorporated into the normal gene complex; those which cannot, remaining to produce a form of polymorphism.

During the past decade, Hovanitz has undertaken a series of ecological and genetic studies of the genus *Colias*. An intensive investigation of California populations of *Colias eurytheme,* a "species" that hybridizes freely with *Colias philodice,* has shown that the two female forms tend to differ in habits, optimal habitat, and speed of development as well as in color. The alleles that control the color dimorphism are apparently pleiotropic; of the two female forms, the pale one is relatively more active during the early and late daylight hours, relatively more numerous in northern populations and those at higher altitudes, and generally first to emerge in each brood. The frequency of the white allele in any population remains more or less constant from year to year, despite seasonal fluctuation in response to changes of temperature and light, but it decreases in a clinal manner from northern to southern populations. The species as a whole, through its dimorphism, assumes a plasticity that enables it to occupy a greater range embracing a wider variety of environments (*14*).

Human polymorphism includes such widely different characters as the blood groups, the ability to taste phenylthiocarbamide, and the presence of hair on the middle segment of the fingers. That these polymorphisms occur is indisputable, but the explanation of their occurrence poses a problem. Dobzhansky (*6*), favoring the view that these are adaptively neutral (or virtually adaptively neutral) traits, perhaps maintained by opposed mutation rates, suggests that the different frequencies of these traits in different human populations may be due to genetic drift in effectively small populations or to interaction of genetic drift and natural selection. Ford (*2*), on the other hand, proposes that human polymorphism may be of a balanced nature involving differential viability of, for example, different blood types. Selection in some cases may be for (or against) effects of the genes other that those that we recognize. Ford also points out that "Haldane has suggested that the polymorphism of rhesus is of the transient kind, owing to the elimination of heterozygotes . . . by . . . haemolytic disease of the newborn. If unopposed this would tend rather rapidly to reduce the *rh* gene (rhesus-negative) to its mutation frequency, and Haldane considers that its present status is



The white (top), lemon-yellow (center), and orange-yellow (bottom) forms of *Colias christina,* from Alberta, Canada. The difference between white on the one hand and orange- or lemon-yellow on the other is due to a single dominant gene. The difference between the lemon-yellow and the orange-yellow forms depends on several genes. In British Columbia virtually all the females of *C. christina* are white; in Arizona almost all are yellow. In intermediate regions both types occur in the populations in varying proportions. [From Wm. Hovanitz, "Polymorphism and Evolution," in *Symposia of the Society for Experimental Biology,* No. VII. The Company of Biologists, Ltd., Cambridge University Press]

due to crossings between races which were respectively rhesus-positive and rhesus-negative to a predominant extent."

Thus the nature of human polymorphisms remains an enigma. They are apparently persistent, for the anthropoid apes have been shown to be similarly polymorphic for the ability (or inability) to taste phenylthiocarbamide and for the A, B, O blood groups, a fact indicating that in all probability these traits existed in the common ancestor of man and the anthropoid apes.

The most universal, yet most remarkable, illustration of balanced polymorphism is the phenomenon of sex, in which the dimorphism expressed in male and female pervades not only morphology but physiology and behavior as well. The mechanism of sex chromosomes, by which one sex is XX and the other XY or XO, always assures the next generation of a 1:1 sex ratio, while the sexual mode of reproduction itself promotes dynamic variability.

The major evolutionary significance of polymorphism is this: it makes for an intraspecific heterogeneity that is adaptive and not random, thereby permitting the species to exploit more fully the various environments that it encounters and to face more successfully environmental change. It may fairly be said that polymorphism within a species is analogous to the processes of speciation and adaptive radiation that take place on higher taxonomic levels.

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One may also imagine, that in criminal hands radium might become very dangerous, and here we ask ourselves if humanity has anything to gain by learning the secrets of nature, if it is ripe enough to profit by them, or if this knowledge is not harmful. The example of Nobel's discoveries is characteristic: powerful explosives have permitted men to perform admirable work. They are also a terrible means of destruction in the hands of the great criminals who lead the peoples towards war.

I am among those who think, with Nobel, that humanity will obtain more good than evil from the new discoveries.—Pierre Curie, 1905.

Mathematics and Natural Philosophy

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TO every one of us, the first revelation of the power of mathematical reasoning in its simplest form was the acquaintance with numbers and their use. From remembrances of our own childhood and the teaching of our children, we have all learned how playful counting is gradually replaced by a more conscious appreciation of the powerful tool for ordering manifolds of things and events that is represented by the rules of addition, subtraction, multiplication, and division. Recalling our education in elementary mathematics, we are likewise reminded of the wonderful experience in our early youth when we learned to estimate distances and heights of trees by the simple geometric constructions that were used by the ancient Egyptians and Mesopotamians with such skill in both geodesy and astronomy.

The significance of the study of mathematics for the development of logical thinking surely cannot be overestimated, and we must realize that every student in his own mind, although in far easier circumstances and with correspondingly greater speed, must travel step by step along the same ever more lofty paths that mankind has wandered on and paved through the ages. A milestone on this climb was reached in ancient Greece, where, at the same time when art flourished in unsurpassed measure, the endeavors to base mathematical science on clearly stated logical principles succeeded to a degree that evokes our admiration and presents us with an everlasting challenge.

I need not stress the invaluable exercise in stringent argumentation that Euclid's elements still offer or how much we learned by the profound exploration of geometric proportions that led Eudoxus to the distinction between so-called rational and irrational numbers, which was basic for ever wider mathematical generalizations. The awareness in the minds of the Greek philosophers of the paradoxes encountered in problems involving infinite sequences such as that in the humorous tale about the race between Achilles and the tortoise sharpened the demands that were made on mathematical proofs. An instructive illustration in this respect is Archimedes' reluctance to rely on the methods, akin to modern infinitesimal calculus, by which he first derived his famous formulas for the volume of pyramids and spheres.

Appreciation of mathematics as a guide in natural philosophy also dates back to the days of the ancient Greeks. We all know how Pythagoras emphasized the importance of simple numerical relationships for musical harmonies as well as cosmology and how much significance the study of regular polyhedrons had for Plato's ideals of beauty and perfection. Among the lasting contributions of Greek mathematicians to physical science, we think especially of the laws of equilibrium of supported and floating bodies that Archimedes, with unfailing intuition, founded on simple arguments of symmetry and balance. In the treatment of dynamic problems, however, great difficulties long stood in the way of eliminating arguments that were motivated by the feeling of exertion experienced in our own movements and by the purposes behind our actions.

Liberation from the Aristotelian approach to dynamics was, as is well known, first accomplished at the time of the Renaissance when Galileo recognized the elementary character of uniform motion and the restricted application of the idea of forces to the alterations of such motion. On this basis, Newton built the marvelous edifice of classical mechanics that—both because of its immense power and scope and because of its adaptation to mathematical calculation—came to stand as an ideal model for scientific explanation and led to the so-called mechanistic conception of nature. Besides, in the analytic geometry of Descartes, the appropriate mathematical tools were found in differential calculus to which Newton himself, equally eminent as a physicist and as a mathematician, contributed so fundamentally.

This revolutionary development initiated an extremely intimate correlation between physical and mathematical research; discoveries in physics presented mathematicians with new challenges, and, in turn, mathematical abstractions and generaliza-

tions furthered the clarification of physical problems. As a typical example, we may recall how the studies of heat conduction inspired Fourier to develop the harmonic analysis that up to now has remained an important branch of pure mathematical research and has proved more and more indispensable to innumerable domains of physics. We may also mention the interplay between Faraday's fundamental research in electricity and magnetism and Maxwell's theory of electromagnetic fields, which inspired the development of mathematical disciplines such as vector and tensor analysis that have been so fruitful in many fields of physical science.

A very impressive account of the powerful tools that physicists now possess—thanks to the ingenious work of mathematicians in the later centuries—is given in the masterly treatise by Courant and Hilbert on the methods of mathematical physics. In this work, invaluable to every student, a lucid exposition is given of logical generalizations that not only have proved to be of extreme fertility in the explorations of multifarious problems within the domain of classical physics but have also shown themselves to be equally inspiring for the elucidation of the novel problems with which modern developments in physical science have confronted us.

The new and broader approach to the description and comprehension of natural phenomena originated in the recognition of the limited scope of the very ideas of absolute space, time, and causality on which the mechanical conception of nature rested. The first hint came, as is well known, from refined optical measurements that demonstrated the absence of the expected influence of the motion of the earth around the sun and revealed that observers moving relatively to each other at large velocities will coordinate phenomena differently. In fact, not only may such observers take different views of shapes and positions of rigid bodies, but events at separate points of space may to one person appear to be simultaneous and may by another be judged to occur at different times.

Far from entailing confusion and complication, the recognition of the extent to which description of physical phenomena depends on the standpoint of the observer proved to be a powerful inspiration to establish general physical laws common to all observers. I need hardly recall Einstein's discovery of the universal relationship between energy and mass or how, by stressing the equivalence from the observational standpoint of the effect of gravitational fields and accelerated frames of reference, he deeply remolded Newton's ideas. The general theory of relativity, which broadened our horizon and gave our world picture a unity surpassing all previous imagination, is surely one of the greatest triumphs of rational human thinking.

For my theme, it is of principal interest that mathematical generalizations that were developed without reference to practical applications but merely in the pursuit of logical harmony have offered adequate tools for the realization of Einstein's great program. Abandoning not only the ideas of absolute space and time but even Euclidean geometry as the foundation, Einstein took recourse to a curved four-dimensional Riemannian space-time metric that automatically accounts for gravitational effects and for the singular role of the speed of light that represents an upper limit for any consistent use of the physical concept of velocity. Mathematicians had indeed gradually become familiar with abstractions of this kind through a development of non-Euclidean geometry and its various models.

Despite all the new features, it was possible in relativity theory to retain and even to refine the deterministic description that is characteristic of classical physics. An inherent limitation of the very idea of causality has, however, been revealed in the last decades by the exploration of the atomic constitution of matter, which was made possible by modern developments in experimental technique. It is interesting to note that, although the assumption of a limited divisibility of substances goes back to antiquity, it was up until quite recent times considered to be a hypothesis for which no direct verification could be obtained. With the great progress in chemistry and physics in the last centuries, atomic ideas proved yet more fruitful, and in particular it was found possible to develop statistical mathematical methods of treating the average behavior of systems consisting of a large number of particles and in this way to account for the empirical laws of thermodynamics. A decisive step was the elucidation by Boltzmann of the general relationship between the concept of entropy and the probability of the degree of order of the state of such systems.

This great accomplishment was indeed the clue to the analysis of the regularities of thermal radiation that, in the first year of this century, led Planck to his epoch-making discovery of the universal quantum of action. In pointing to a feature of indivisibility in physical processes that is quite foreign to the mechanistic conception of nature, Planck's discovery revealed that the laws of classical physics are idealizations that are applicable only to the description of phenomena where the actions involved are sufficiently large to permit neglect of the quantum. Whereas this condition is amply fulfilled in phenomena on the ordinary scale, we meet

in atomic processes regularities of quite a new kind, regularities that defy the deterministic pictorial description. Very striking illustrations are afforded by the well-known dilemmas regarding the properties of electromagnetic radiation as well as of material corpuscles, evidenced by the circumstance that in both cases contrasting pictures as waves and particles appear equally indispensable for the full account of experimental evidence.

Here we are clearly in a situation where it is no longer possible to define unambiguously attributes of physical objects independently of the way in which the phenomena are observed, and especially to ignore the interaction between objects and measuring instruments, the disregard of which is characteristic of the mechanistic conception of nature. This situation has demanded a new revision of the foundations for the description and comprehension of physical experience. On the one hand, we must realize that however far the phenomena transcend the scope of classical physics, it is obviously necessary to describe the experimental arrangement and the observations in plain language suitably supplemented with technical physical terminology. On the other hand, just the necessity of accounting for the functioning of the measuring agencies on classical lines excludes in principle in proper quantum phenomena an accurate control of the reaction of the measuring instruments on the atomic objects.

This circumstance prevents in particular the unrestricted combination of space-time coordination and the dynamic conservation laws on which deterministic description in classical physics rests. In fact, any unambiguous use of the concepts of space and time refers to an experimental arrangement that involves a transfer of momentum and energy, uncontrollable in principle, to instruments such as measuring rods and synchronized clocks, which are required for fixing the reference frame. Conversely, an account of phenomena governed by conservation of momentum and energy involves in principle a renunciation of detailed space-time coordination.

The essential indivisibility of proper quantum phenomena finds logical expression in the circumstance that any attempt at a well-defined subdivision would require a change in the experimental arrangement that precludes the appearance of the phenomenon itself. Under these conditions, it is not surprising that phenomena observed with different experimental arrangements appear to be contradictory when it is attempted to combine them in a single picture. Such phenomena may appropriately be termed complementary in the sense that they represent equally important aspects of the knowledge obtainable regarding the atomic objects and only together exhaust this knowledge. The notion of complementarity implies no arbitrary renunciation of our accustomed demands on physical explanation but simply refers to our position as observers in this new domain of experience.

Actually, it has been possible by the concerted efforts of a whole generation of theoretical physicists to develop a rational generalization of classical mechanics that permits a complete account of a wide field of experience along the lines of the complementary mode of description. In this quantum mechanical formalism, the ordinary kinematic and dynamic variables are replaced by operators, subject to a noncommutative algorism involving Planck's constant. We are here again dealing with mathematical abstractions already widely explored; for example, it was early realized that the composition of rotational movements of rigid bodies as a sequence of rotations around different axes is dependent on the order in which such operations are performed.

In the quantum mechanical terminology, the noncommutabilty of the symbolic operators directly reflects the mutual exclusion of experimental arrangements that permit the accurate definition of the corresponding physical quantities. Moreover, the reciprocally restricted applicability of kinematic and dynamic variables in the quantum mechanical description of the state of a physical system finds quantitative expression in Heisenberg's indeterminacy relationships which proved to be of fundamental importance for the clarification of the situation, especially with regard to the limits of the customary ideal of causality.

In conformity with the circumstance that several individual quantum processes may take place in a given experimental arrangement, the predictions of the formalism concerning observations are of an essentially statistical character. It must be realized, however, that in this respect we are presented, not with an analog to the use of probability considerations in the account of the behavior of complicated mechanical systems, but with the impossibilty of defining any directive for the course of individual processes beyond those afforded by the self-consistent generalization of deterministic mechanics.

For anyone who through the years has been concerned with the difficulties and paradoxes in quantum physics, it is indeed a deep satisfaction that logical order should be attained to such degree by means of the subtle methods offered by mathematical science. Truly, it has been a wonderful experience to witness how an immense amount of experimental evidence regarding atomic and molecular spectra, chemical bonds, and radioactive processes in the course of a few years was accounted for in

detail and brought into unique connection with simple data regarding inertial masses and electric charges of the particles of which all atoms are composed.

We are confronted here with regularities fundamental to the properties of matter that, although they are quite beyond the scope of the mechanical principles so fruitful in diverse fields of technology, nevertheless lend themselves to mathematical formulation and numerical calculation. In this connection, it is also important that the existence of high-speed computers—such as the wonderful UNIVAC installed in the Institute of Mathematical Sciences at New York University—which have initiated great advances in the treatment of many problems within the domain of classical physics, holds similar promises for the exploration of atomic problems.

The general lesson of the role that mathematics has played through the ages in natural philosophy is the recognition that no relationship can be defined without a logical frame and that any apparent disharmony in the description of experiences can be eliminated only by an appropriate widening of the conceptual framework. This lesson, familiar to mathematicians, and conspicuous in studies of the foundations of their science, has been enforced by the development of physics in a way that has a bearing on many other fields of human knowledge and interest in which we meet with similar situations in the analysis and synthesis of experience.

The aims of the physicist, however, are in part purely intellectual; he strives to understand the Universe on account of the intellectual pleasure derived from the pursuit, but he is upheld in it by the knowledge that the study of nature's secrets is the ordained method by which the greatest good and happiness shall finally come to the human race.

Where, then, are the greatest laboratories of research in this city, in this country, nay, in the world? We see a few miserable structures here and there occupied by a few starving professors who are nobly striving to do the best with the feeble means at their disposal. But where in the world is the institute of pure research in any department of science with an income of $100,000,000 per year? Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But $100,000,000 per year is but the price of an army or of a navy designed to kill other people. Just think of it, that one percent of this sum seems to most people too great to save our children and descendants from misery and even death?

But the twentieth century is near—may we not hope for better things before its end? May we not hope to influence the public in this direction?—Henry A. Rowland.

Techniques Used in Studies with High-Intensity Gamma Radiation

L. E. BROWNELL AND J. V. NEHEMIAS

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THE problem of the ultimate disposition of fission products, which result from the operation of nuclear reactors, has stimulated research into possible industrial uses for these radioactive materials (*1*, *2*). Because high-level gamma radiation sources prepared from fission products were not available when this research was initiated at the University of Michigan, cobalt-60 was used as a source of gamma radiation. The experiments with gamma radiation were begun with a hollow cylinder of radioactive metallic cobalt produced in the nuclear reactor at Brookhaven National Laboratory. The cylinder has a length of 13 inches and an inside diameter of about 1⅜ inches; this limits the maximum volumetric capacity to one large test tube. The gamma radiation flux inside this source is of the order of 45,000 rep (roentgen equivalent physical) per hour.

In order to obtain a more intense radiation field and to permit the irradiation of larger volumes of material, a second radiation source, 10 times as powerful and of different geometric arrangement, was designed and acquired. The inner diameter of the second source is 6¾ inches and the length is 10 inches. The radiation field both inside and outside the cylinder is used. This makes possible the irradiation of much larger volumes of material at dosage rates varying from 250 to 150,000 rep per hour outside the cylinder and 200,000 rep per hour inside the cylinder. The design and proposed uses of this high-intensity gamma radiation facility and some of the problems encountered in the first year of operation have been reported in the literature (*3*).

The new source consists of 100 rods of metallic radiocobalt, each ¼ inch in diameter and 10 inches long, jacketed in aluminum to prevent corrosion. These rods were neutron-irradiated in the NRX reactor at Chalk River, Ontario. The 100 rods are arrayed in an aluminum rack to form a hollow cylinder, as is shown in Fig. 1. The central axial space receives the highest radiation flux and will accommodate a commercial No. 10 can (6-3/16 inches in diameter and 7 inches long). The source is used in a "radiation cave," as is illustrated in Fig. 2. The radiation room is 8 by 8 by 11 feet. Any sample that will fit in the room may be subjected to irradiation treatment. If uniformity of irradiation throughout a sample is important, however, allowance must be made to permit rotation of the sample.

When the source is not in use, it is stored under 10 feet of water. Figure 3 shows the rods in the storage position under water as photographed by the light of the Cerenkov radiation. The water shielding enables the operator to enter the cave for the purpose of arranging experimental apparatus or placing samples around the source position without experiencing significant exposure to radiation. Only when the operator has left the cave and closed and bolted the entrance door can the source be raised into its operating position in the cave. The source is raised by a hand-operated winch located outside the cave in the laboratory. When the source is in the operating position, a mechanical interlock prevents the entrance door from being opened.

A concrete barrier wall in the cave forms a simple labyrinthine passage that permits the use of an ordinary door at the entrance to the cave. An opening in this door and two 6-foot-high mirrors permit observation of experiments in process in the radiation cave.

Experimental Techniques

In addition to several experiments of a routine nature that could have been accomplished with

less versatile radiation sources, a number of experiments have been performed that make use of the unique versatility inherent in this radiation facility.

In the experiments with canned raw frozen foods and canned fresh foods, and in the animal feeding experiment, the destruction of microorganisms by gamma irradiation was studied with particular emphasis on the radiation sterilization and pasteurization of foods. Detailed experiments are underway to investigate the effects of total dose, dosage rate, temperature during irradiation, temperature during storage, length of storage, packaging procedures, and other parameters on bacterial populations, as well as the flavor, color, and nutritional value of the irradiated food.

Canned raw frozen foods. An annular insulated container was designed and constructed by the personnel of the American Can Company for the purpose of irradiating canned uncooked food in the frozen state. Figure 4 illustrates this "radiation ice box" in use. In an irradiation experiment involving a large number of containers, such as that shown, 26 commercial No. 2 cans (3⅜ inches in diameter and 4½ inches long) have been simultaneously treated at a dosage rate of 100,000 rep per hour. The cans were periodically rotated during the irradiation, and the unit was kept closed to maintain thermal insulation. Experiments have been performed at ice temperature and at Dry Ice

Fig. 1. A model of the high-intensity gamma radiation source. An aluminum rack contains two rows of 50 cobalt rods, each jacketed in aluminum to minimize corrosion.

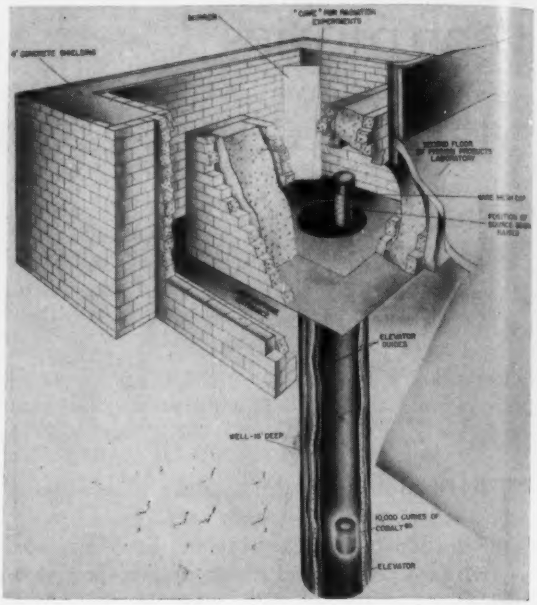


Fig. 2. Radiation "cave," showing the labyrinthine passageway, water storage well, shielding, and viewing mirrors. When preparatory work in the cave is complete, the operator, from outside the cave, raises the source from the well up into the wire-mesh cap.

temperature. The temperature was controlled by placing containers of ice or Dry Ice in the box around the outside of the samples.

Canned fresh foods. Several experiments have been performed using commercial cans at various positions, as shown in Fig. 5. Varying dosage rate in this manner makes it possible to provide a wide range of dosage values with a single exposure. In the case of the experiment illustrated, an exposure time of 8 hours would yield the dosage shown in Table 1. In such an experiment, those cans located outside the source cylinder must be rotated, either continually or periodically, to improve the degree of uniformity of dosage throughout the can.

Animal feeding experiment. A long-term animal feeding and breeding experiment using 120 parent albino rats is underway at our laboratory to evaluate the wholesomeness of a diet that receives a radiation dose of 4 million rep. The wholesomeness of the food is defined as its ability to support normal growth, reproduction, and so forth, without any toxic or other undesirable effects. The maximum requirement of the irradiated diet for this experiment is expected to be 10 pounds per day.

In pilot studies with animals that were fed a diet which had received up to 50 megarep of radiation, no acute toxicity was apparent. However, a

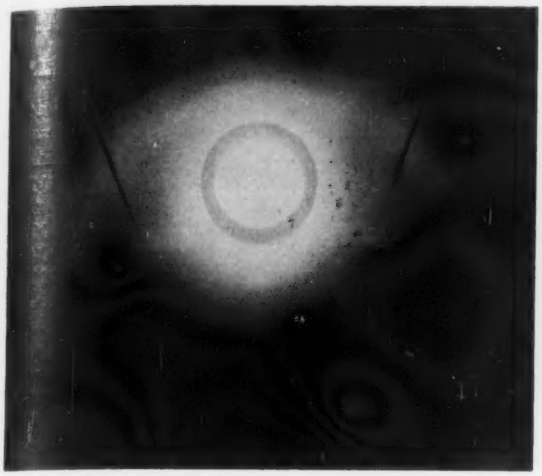


Fig. 3. Gamma radiation source under water taken by the light of the Cerenkov radiation resulting from the interaction of the gamma radiation and the water.

Fig. 4. "Radiation icebox," designed to permit irradiation of canned fresh food in the frozen state. During an experiment, the spaces are filled with ice or Dry Ice, depending on the temperature desired, and the box is thermally sealed.

Fig. 5. Array of commercial No. 10 cans in position around the radiation source to receive dosages ranging from 2500 to 250,000 rep per hour, as detailed in Table 1.

Table 1. Dosage rates delivered to samples placed as illustrated in Fig. 5.

Can	Distance from center of can to wire basket (in.)	Dosage rate (10^3 rep/hr)	Total dose (10^3 rep)
A		250.	2000
B	3	87.5	700
C	4.25	62.5	500
D	5.5	50	400
E	6.75	37.5	300
F	9.25	25	200
G	15	12.5	100
H	24	6.25	50
I	42	2.5	20

Fig. 6. Half of a hog suspended near the radiation source. The dosage rate at the hind quarter is appreciably less than it is at the fore quarter. In such circumstances it is necessary to invert the sample if uniformity of irradiation is required. Two mirrors were used to obtain the photograph. [Courtesy *Life* magazine]

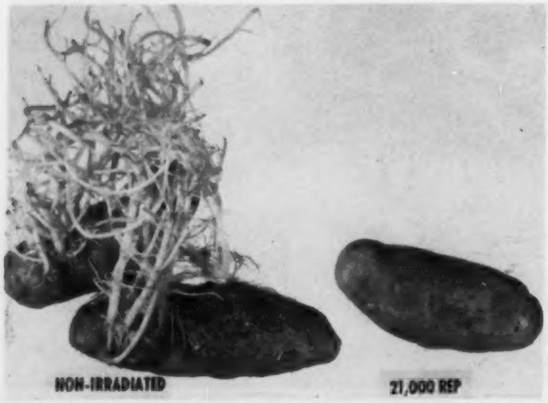


Fig. 7. Comparison between sprouted control potato and unsprouted irradiated potato after 4 months' storage.

marked vitamin deficiency was observed when the complete diet was irradiated with a 20-megarep dose. This deficiency was removed by supplementing the diet with the water-soluble vitamins. With a dosage of 2 megarep, no vitamin deficiency was observed when the complete diet was irradiated.

Pork. A radiation treatment of pork at a much lower level of 20,000 rep has been found sufficient to prevent the reproduction of trichina larvae (*4*). Experiments have been performed in this study in which quarters and halves of hogs have been irradiated. Figure 6 shows a half hog, as seen from outside the cave through a double mirror system, in position to be irradiated. The absorption characteristics of pork were studied by use of gamma radiation and ferrous-ferric dosimetry. The half-value thickness was determined to be 10½ inches for the radiation from cobalt-60.

Vegetables and grain. The same low level of treatment, 10,000 to 20,000 rep, has been found to prevent reproduction of the insects that infest wheat and other grains (*5*). Radiation dosages sufficient to treat flour or wheat for insect infestation were observed to have no undesirable effects on the taste and baking qualities of wheat flour, whereas radiation dosages of more than 100,000 rep were considered to have an undesirable effect on the qualities of bread, cake, and biscuits made from irradiated flour (*2*).

Low dosages of gamma radiation (7000 to 21,000 rep) were found to prevent the sprouting of storage potatoes (*2, 6*). Taste-panel tests showed no off-flavor problem with such irradiated potatoes. Chemical analysis showed that irradiated, stored potatoes had a lower sugar content than the stored controls. The same dosages of gamma radiation also increased the storage life of onions (*2*). Although the radiation does not prevent sprouting of onions, the sprouts grow only a short distance and then cease growing. Several sacks containing 100 pounds of such produce can

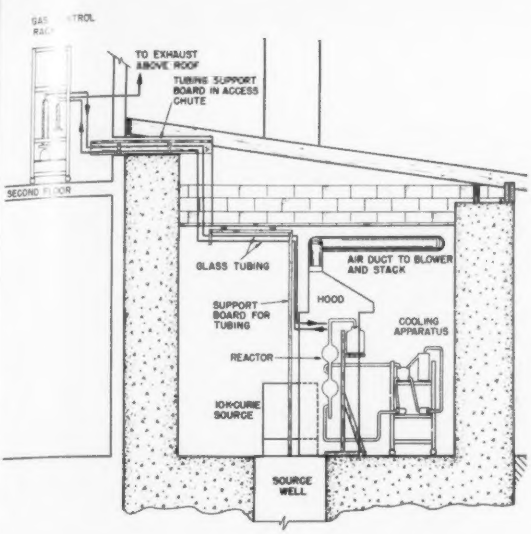


Fig. 8. Sectional view of the radiation cave, showing the arrangement for experimental apparatus for chlorine, reaction temperature, and so forth, which are controlled from the second floor.

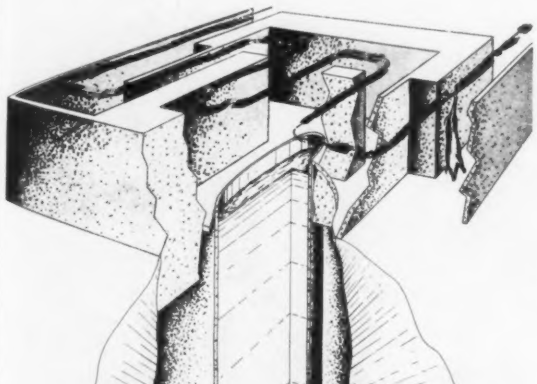


Fig. 9. **Irradiation facility for treating whole hogs. As in the experimental cave (Fig. 2), the source is stored under water when it is not in use to permit safe entry into the radiation room.**

be conveniently irradiated simultaneously around the outside of the source. Figure 7 shows some irradiated potatoes and controls that were stored at a temperature of 50°F for 6 weeks subsequent to irradiation.

Chemical reactions. Gamma radiation has been found to catalyze certain chemical reactions, such as the chlorination of aromatic compounds and the polymerization of olefins. The flexibility of dosage rate and the space available in the cave for equipment and manipulation make such experiments possible on a practical scale. Studies on the polymerization of ethylene under gamma radiation were made using various temperatures and pressures. At a temperature of 220°C and a pressure of 1000 pounds per square inch, an oily liquid was obtained; tough or waxy solids were obtained at lower temperatures.

Toluene was chlorinated under gamma radiation, and the products obtained by dehydrohalogenation and subsequent oxidation of the chlorinated toluene confirm the hypothesis that chlorine is added to the ring of toluene under gamma radiation.

A design was developed for a chemical plant to chlorinate benzene under gamma radiation for the production of insecticides (*2*). Sources of cesium-137, 6-month-old mixed fission products, and cooling reactor-fuel elements were compared. Estimated costs for producing the addition product by using gamma radiation compared favorably with existing prices of the product prepared under ultraviolet radiation. Figure 8 is a sectional view of the radiation cave showing the arrangement of the apparatus used to study the chlorination of benzene and toluene.

Design of Commercial Facilities

On the basis of some of these experimental results, three commercial irradiation facilities have been designed and will be reported in the periodic literature. The first irradiation facility, shown in Fig. 9, uses 1.5 megacuries of cesium-137 as a radiation source and is designed to provide a minimum dose of 25,000 rep to whole hog carcasses at a rate of 2000 hogs per day. The estimated net cost of this treatment, including amortization of the investment over a 5-year period, is less than ¼ cent per pound of pork irradiated. The well of water used to shut off the radiation, the barrier wall, and the labyrinthine entrance of the experimental radiation cave have been applied to advantage in this design of a commercial radiation facility.

The second facility, illustrated in Fig. 10, also uses 1.5 megacuries of cesium-137 and is designed

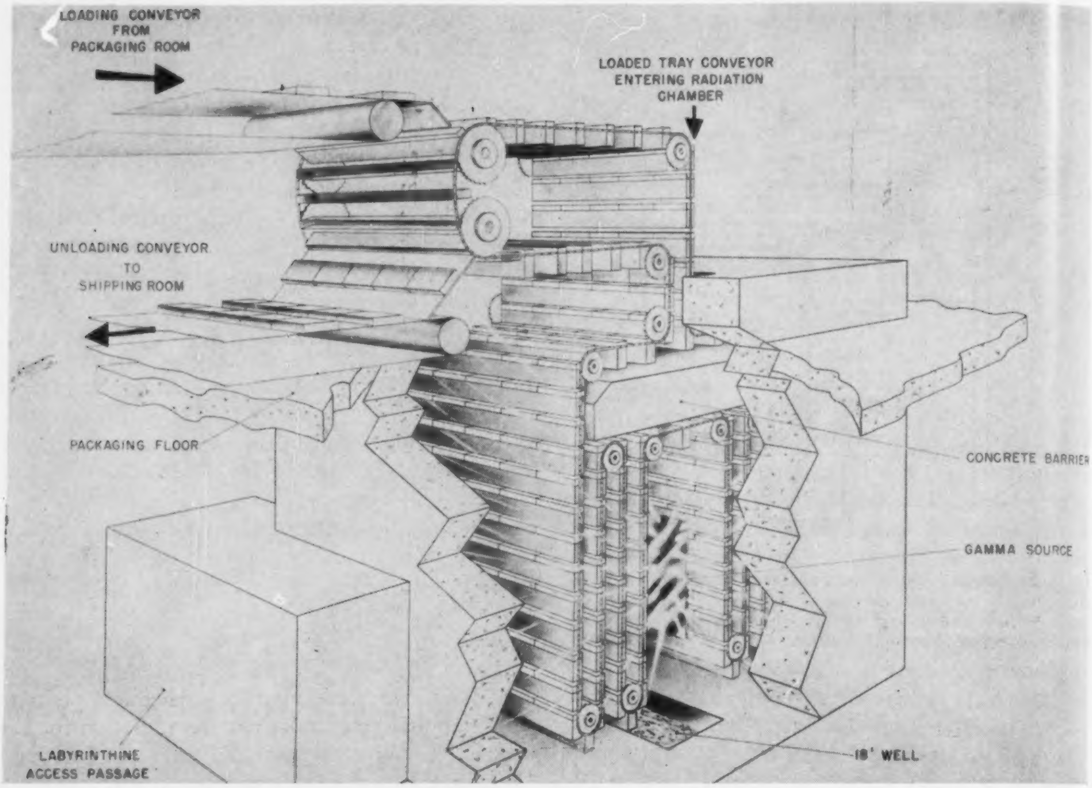
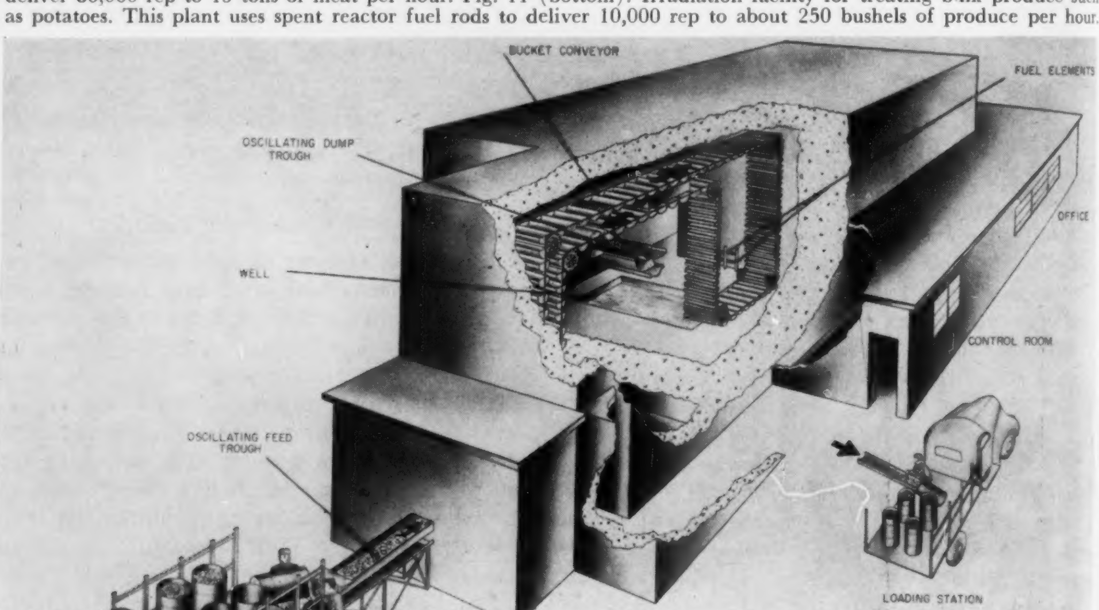


Fig. 10 (top). Irradiation facility for treating packaged goods in commercial quantities. This plant was designed to deliver 80,000 rep to 13 tons of meat per hour. Fig. 11 (bottom). Irradiation facility for treating bulk produce such as potatoes. This plant uses spent reactor fuel rods to deliver 10,000 rep to about 250 bushels of produce per hour.



to "pasteurize" meat—that is, to double or triple the refrigerator shelf life of raw meat by killing most but not all of the microorganisms with a relatively small dose of radiation. Experimental results indicate that a treatment of 80,000 rep is sufficient to pasteurize meat by irradiation without producing off flavors. This facility is designed to treat 13 tons of meat per hour at an estimated net cost of 1/14 cent per pound. The facility for pasteurization is estimated to be 5 times as efficient in using radiation as the first design of a commercial facility, because the meat may be more efficiently packed as an absorber.

The pasteurization of fresh meat by irradiation may make possible a new method of wholesaling fresh meats in which the meat would be cut, prepackaged, and pasteurized at the packing house. This would (i) eliminate about 30 percent of the shipping weight, (ii) reduce the cost of packaged meat, (iii) increase the refrigerator shelf life of the meat, (iv) eliminate the possibility of trichinosis in man from eating infected pork. The second commercial radiation facility could also be used to treat sacks of produce for the prevention of sprouting and to sterilize cartons of canned food.

The third facility, illustrated in Fig. 11, makes use of spent fuel rods from a nuclear reactor to irradiate potatoes. Such rods are commonly stored under water for a period of time after removal from the reactor before chemical processing. A seasonal application, such as the irradiation of potatoes on the way to market, might operate only a few months a year and make efficient use of these short-lived radiations during the operation period. This facility is designed to deliver 10,000 rep to about 250 bushels per hour at a cost of 6 cents per bushel.

Research on the uses of gamma radiation is at an early stage—too early to appraise the possibilities and limitations of such applications. However, many results have been promising and the studies are being continued with optimism for the future.

References and Notes

1. A study of this program has been supported at the Engineering Research Institute of the University of Michigan through a contract with the U.S. Atomic Energy Commission since early in 1951. In addition, the Michigan Memorial Phoenix Project, a War Memorial Center created to explore the ways and means by which the potentialities of atomic energy may become a beneficent influence in the life of man, is supporting, among other studies, an investigation of some of the uses of gamma radiation. The research supported by the Atomic Energy Commission at the University of Michigan and by the Phoenix project on uses of gamma radiation has been conducted in the Fission Products Laboratory.
2. L. E. Brownell, *et al.*, "Utilization of the gross fission products" *Progress Reports* No. 1 to No. 7, U.S. Atomic Energy Commission (C00-86, -90, -91, -124, -196, and -198).
3. L. E. Brownell, *et al.*, *Chem. Eng. Progr.* **49**, 569 (1953); J. V. Nehemias, *et al.*, *Am. J. Phys.* **22**, 88 (1954); J. V. Nehemias, *et al.*, *ibid.* **22**, 511 (1954).
4. H. J. Gomberg and S. E. Gould, *Science* **118**, 75 (1953); H. J. Gomberg, *et al.*, *Nucleonics* **12**, No. 5, 38 (1954); **12**, No. 9, 66 (1954).
5. C. C. Hassett and D. W. Jenkins, *Nucleonics* **10**, No. 12, 42 (1952).
6. A. H. Sparrow, "Quarterly Progress Report" (1 July–30 September 1953), Brookhaven National Laboratory, U.S. Atomic Energy Commission BNL 259 (S-19).

Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labor in the minute sifting of numerical results—LORD KELVIN, *Report of the British Association for the Advancement of Science* **41**, *91* (1871).

BOOK REVIEWS

Augustine to Galileo. The history of science A.D. 400–1650. A. C. Crombie. Harvard Univ. Press, Cambridge, Mass., 1953. xv + 436 pp. Illus. + plates. $8.

First there were the Greeks, then the Romans, then darkness fell. At long last, "God said, *Let Newton be*! and all was light!" Although this is parody, doubtless there is justice in the charge that for many this gaping discontinuity from the ancients to the 17th century epitomizes the development of Western science. Recently, historians of ideas in the Middle Ages have been busy exposing the libel, circumstantially detailing the "modern" thoughts and innovations of men in monasteries and universities during the later Middle Ages. For the nonspecialist, A. C. Crombie's book adds materially to the growing literature dedicated to setting the record straight. The major part of his work is given over to the period from the 13th century, the so-called medieval renaissance, through the 17th-century scientific revolution. The reader who already has a broad knowledge of the period will not find many surprises in the factual account itself, except perhaps the exposition of Grosseteste's contributions, for which the author utilizes, naturally, his own earlier work on this 13th-century figure.

Crombie's history is given special interest by his development of the by now familiar thesis that the "modern" scientific view did not spring full-blown from Galileo's head but has its earliest roots in the 13th century. The contributions of Grosseteste in optics, Roger Bacon and Theodoric on the rainbow, Jordanus in mechanics, Fibonacci and Jordanus in mathematics, Buridan and Oresme in dynamics, and of many others are cited in evidence. Although there is certainly general agreement with this thesis of continuity, other specialists in the history of science may yet challenge Crombie on many points. Following Duhem, Crombie argues that the condemnation of the Aristotelian so-called Latin Averroists in 1277 sufficiently shook the authority of the newly discovered *corpus Aristotelicum* to make it possible for subsequent thinkers, even in an age of authority, to follow their own genius, taking from the Philosopher only what was useful without being fettered by what was not. With this, Crombie maintains, modern science began.

But surely the importance he attributes to the events of 1277 is debatable. Duns Scotus' concern hardly a generation later with the grounds of certainty in knowledge, the skepticism of William of Ockham in the next generation about our ability to attain knowledge of the "essences" of things, and the preoccupation of both Scotus and Ockham with problems of causality and induction probably made these two men, at least indirectly, influential above all others in the development of science. Crombie agrees. It must be said then that these two Franciscans stood, at least in some respects, in the Augustinian tradition, and that in the ancient and deeply rooted anti-Aristotelianism of the Augustinians, the anti-Averroism of the 1270's was but one incident among many. There is, moreover, the complication that Galileo's university, Padua, where anti-Aristotelian science flourished, was also the center of Averroism, which, in the meantime, had felt the impact of the Ockhamite "modern way." (The Averroists were first *officially* condemned by a Lateran council as recently as 1513; the 1277 pronouncement was merely the act of a hard-pressed French bishop.) For the specialist, the precise demarcation of these historical lines is, of course, the heart of the matter and rightly so. I dare say that from this battle of the books Crombie will not emerge wholly unscathed for his sometimes rather flat-footed assertions about matters still either obscure or controversial.

Nor will Crombie easily slip through the philosophers' net. It may be questioned, for example, whether his modernized version of the medieval "saving the appearances" doctrine is indeed as validated by recent science as Crombie believes. During the Middle Ages, the distinction, discarded by Galileo, between "physics" and "mathematics" was turned to the service of the perpetual controversy over the relation of faith to reason. Mathematical description, such as Ptolemy's epicycles, was held not to compromise the officially approved Aristotelian cosmology of crystalline spheres, since it merely "saved the appearances" without actually describing physical reality.

This is not the place to analyze what is right and what is wrong with the view sometimes called "positivism" or conventionalism, the view that, since, as Crombie rightly says, different theories may explain the same set of facts, no theory is either true or false, only a useful manner of speaking. However, whether science is just an expedient way of talking about the world of experience or whether it describes things as they really are is far from uncontroversial or, at least, far from a simple *Yes* or *No* answer. It may further be asked whether, as the phrase is here used, "save the appearances" does not do less than justice both to the Church's abuse of its power and to the genius of Galileo who, we are told, from "not understanding himself" resisted the positivist doctrine. Were the Church leaders really more prescient about these matters than Galileo? Crombie does not actually say it, but one senses that he would like to believe they were.

Nevertheless, despite whatever historical and philosophic disagreements scholars may have, the book stresses what for most nonspecialists needs stressing. It focuses attention on the considerable amount of intellectual activity and controversy that went on during the Middle Ages. Nor is Crombie unaware of the difficulties still facing the continuity thesis, since, as he emphasizes, an indubitably new type of question about the physical universe arose in the 17th century. Although he does not bring out as sharply as one would like the revolutionary significance of the new role assumed by space and time in the analysis of motion, he does show

how the application of mathematics to mechanics led to the final rejection of the search for "essential natures" in favor of observable uniformities, and how this new emphasis eventually replaced the old question of a (teleological) *why* by that of a (mechanistic) *what*. Crombie, then, does not depreciate the magnitude of the 17th century's achievement. That it had ties to the past, some to be built on, some to be broken, he fully realizes. Yet there was, despite all "continuity," a scientific *revolution*. Crombie is as sensitive as one should be to the fact that we still lack a full explanation of exactly how it all happened at that time and that place. Here at least he has no pat answers, and very likely there are none.

MAY BRODBECK
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Science in Our Lives. Ritchie Calder. Michigan State College Press, East Lansing; New American Library, New York, 1955. 192 pp. Paper, 35¢.

It is a matter of great importance to present science to the general public, but it is also a task of great difficulty. The author of *Science in Our Lives* is an experienced journalist, chairman of the British Association of Science Writers; he has succeeded remarkably well. Some of his 11 chapters deal with the history, philosophy, or sociology of science (1, 2, 3, 11), some with physical sciences or techniques (4, 5, 7, 9), some with biology and medicine (6, 8, 10). They imply considerable search for information, are skillfully presented, and read very easily.

It is, of course, impossible in principle to inform readers, who are ignorant of the fundamentals, about the latest advances of radioastronomy or immunology, and yet it *must* be done. May this little book be bought by many and help bridge the dangerous chasm between science and the public.

P. LE CORBEILLER
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Early American Science. Needs and opportunities for study. Whitfield J. Bell, Jr. Institute of Early American History and Culture, Williamsburg, Va., 1955. vii + 85 pp. $1.25.

This book is the first publication resulting from a series of conferences sponsored by the Institute of Early American History and Culture, which was established something over 10 years ago under the aegis of the College of William and Mary and Colonial Williamsburg, Inc. The institute serves as a research center dealing with American history up to the end of the Jeffersonian period; the conferences, held in 1952 and 1953, concentrated on needs for investigation in neglected fields. The results of the Conference on Early American Science, as embodied in this small volume, must be described as eminently successful, and the interest and importance of the book are wholly out of proportion to its size.

The book begins with a concise and lucid summary of the conditions of American science up to about 1820 and of the state of knowledge concerning them. This is followed by a quadripartite bibliography, the most extensive section of which comprises selected bibliographies related to 50 early American scientists, chosen with imagination and presented judiciously. The success of the volume rests largely on its recognition of one simple principle, unfortunately usually ignored by the authors of reports citing needs and opportunities, namely, that the form of a lacuna is determined by the configuration of the walls that circumscribe it. In both the survey chapter and the principal portion of the bibliography, the volume points up its desiderata by providing a well-organized and clearly written account of biographical and other historical material in which content, as well as apparatus, is emphasized, and much information of absorbing interest is included. The book concentrates on intellectual, rather than material, resources and is further unique in that it completely escapes a didactic tone. It is highly recommended, not only as a model of presentation, but also for the inherent fascination and importance of the material covered.

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Ethical Judgment. The use of science in ethics. Abraham Edel. Free Press, Glencoe, Ill., 1955. 348 pp. $5.

In his preface, Edel explains that "this book starts . . . [with the] issue of ethical relativity. Its concern is . . . to analyze its general tenet of indeterminacy, and to explore the way in which human sciences can help provide more definite answers to moral judgment." The book is a justification of an empirical ethics founded upon factual evidence, carried on in accordance with the generally accepted methods of science. It takes issue with all forms of semi-a priori absolutism and semi-a priori relativism in ethics. His two chapters criticizing these rejected approaches are probably the best in the book and the best to date in contemporary ethical writing. To my mind he effectively and correctly puts his finger on the defects of the current emotive judgment and linguistic theories, which pose as the up-to-date modes of ethical analysis.

The body of the book is occupied with carefully selected and well-explained references to biological, psychological, cultural, and historical materials relevant to an empirically verifiable theory of ethics—materials that would reduce the degree of indeterminacy in the subject. His bibliographic footnotes are particularly valuable for anyone stimulated to read further in these areas.

The short terminal section on "The theory of the valuational base" is perhaps the least satisfactory por-

tion of the book. Here the author seems to be sketching his positive theory. It is reminiscent of Dewey's formulation of ethics in terms of a problematic situation. One really gets more insight into what Edel is aiming at by studying his earlier Chapter IV. In this chapter he refers to Dewey, and speaks of a "problem field constituted by the relations of persons, aims, circumstances, environment," and of "the contributions of the different sciences . . . regarded as explorations of particular constituents and relations of the field for specialized perspectives" (p. 97). Such a field structure could institute its own ideal of fulfillment and of an ethical solution.

Much remains for Edel to work out and this he promises to do in a future study. The central subject of the present work, however, stands as a much needed clearing of the field of semi-a priori relativisms and a reinstatement of a substantial ethics as a type of verifiable scientific hypothesis.

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Current Trends in Psychology and the Behavioral Sciences. J. T. Wilson, C. S. Ford, B. F. Skinner, G. Bergmann, F. A. Beach, and K. Pribram. Univ. of Pittsburgh Press, Pittsburgh, 1954. xvi + 142 pp. Illus. $4.

To a biologist who is concerned with neural mechanisms of behavior and who has just been exposed for a year at the Center for Advanced Study in the Behavioral Sciences to the implicit or explicit assumption by most of the fellows that behavioral science is limited to parts of social science, this small volume is a welcome oasis. R. A. Patton and the University of Pittsburgh have arranged annual conferences on Current Trends in Psychology, of which this collection of six lectures and an introduction is the latest outcome. Previous volumes have related psychology to social science, to industry, to medicine, to theory, and to itself; with perhaps a fifth of the 45 participants oriented to biology; the present volume relates psychology to behavioral science, and three pieces out of seven are overtly biological.

It is well for the future of psychology and behavioral science that our view of human behavior should penetrate beyond the output of black boxes that happen to be people. I am in agreement with Gustav Bergmann's position in his contribution on "Reduction" that theory and experiment in psychology are welcome at their own (makro) level but that one must hope and seek to translate the theorems into axioms at the physiological (micro) level—and also from the sociological to the psychological levels.

Patton's introduction presents a sound view of stress and correctly relates it to the physiological concepts of homeostasis—which are used, for a change, precisely—to exemplify the problem of definition of terms used in boundary areas. John Wilson is also concerned with definition—of behavioral science—and with the "search for common dimensions which will serve to conceptualize behavioral problems at varying levels of complexity from individual to social, as well as to reduce them to manageable experimental enterprises"—a worthy quest.

The theme of Clellan Ford, who considers potential contributions of anthropology, is manageable enterprises, which, though not experimental, serve to test "hypotheses as general principles governing human social life and culture throughout the world." Ford makes a good case for the use of natural history data collected by anthropologists as cross-cultural checks on hypotheses and describes the ambitious "Human relations area files," a cooperative and continuing effort to make these data really usable.

Fred Skinner outlines his successes with the immediate reinforcement technique in conditioning animal behavior and urges its use in teaching children. His argument is trenchant and I hope it is being explored even though I suspect that it has serious limitations such as the reinforcement's being limited to the overt act (a child indicates the numerical answer obtained to a problem) but not available for the preceding internal events (whether they are regarded as conceptual or neural).

Frank Beach marshals variegated biological and psychosociological studies in an adroit and convincing manner to demonstrate that both the developing system and the external forces acting on it are involved in the outcome. He emphasizes the existence of susceptible periods during development and the basic congruencies in differentiation and growth from the formation of the neural tube to the formation of patterns of emotion and habits of thought. Although he says development depends equally on the system and the environment, I am sure he means only that both must be involved, not that their quantitative weighting cannot vary widely from case to case.

Finally, Karl Pribram writes of a science of neuropsychology and describes some of his grounding experiments on monkeys in which due attention is given both to the changes that are imposed on the central nervous system by the experimenter and to the changes in behavior that are exhibited by the animal. Different cortical zones are identified, each involved separately in a performance, requiring, say, immediate visual choice or visual choice based on preceding cues. A statement that the shift in peck order following amygdalectomy depends on the attitudes of other monkeys as strongly as on the brain damage is experimentally suggested but hardly demonstrated. It is of sufficient importance to deserve a rigorous test.

The most significant relationship of psychology and behavioral science, it seems to me, is that one slices knowledge at an angle to the other. Psychology, economics, and physiology are established disciplines that cut the problem area into vertical slices with their developed methodologies. Behavioral science, cybernetics, and "human biology" are new focuses of interest that cut the same area horizontally with the only resources

yet available—those pooled from the established disciplines. Since, in any case, the same entities or variables emerge for study, illumination from two directions should help exhibit them in the round. In fact, exhibition of the proper units is the crucial step in a developing science; later come their manipulation and quantitation. Economics is relatively advanced because its unit of concern is clear and because vast and quantitative records are available concerning money; behavioral science will advance as the proper variables emerge and as psychology and her sister disciplines supply procedures for manipulating and measuring them.

R. W. GERARD

Center for Advanced Study in the Behavioral Sciences

Politics and Science. William Esslinger. Philosophical Library, New York, 1955. xi + 167 pp. $3.

This is two books in one, with a foreword by Albert Einstein thrown in for good measure. Esslinger presents first of all an argument for a "practical science of politics," which the world needs in order to save itself from destruction. He strongly disapproves of the current fashions in the academic study of international relations; he seems to disagree equally with the Hans Morgenthau school and its theory of national interest and with the Reinhold Niebuhr followers who are oppressed by the tragic dilemmas of international politics.

At the same time he refuses to agree with those who want political science to become scientific by imitating some particular scientific method. He insists very sensibly that the study of politics should be adapted to its own subject matter in a way practical enough to be applied to the real problems of the modern world.

Esslinger weakens his case by oversimplifying it. "Politics," he says, "is not as complicated as any physical science, because the forms of human organization and the possibility of their combination are limited." For example, he says there are only three basic forms of international organization—alliances, confederations, and federations. This kind of oversimplification gets him into deep water when he tries to incorporate another book on a different subject into his single short volume. He mixes in with his plea for a new kind of political science a plea for the establishment of a world government. In spite of his general argument for the importance of measures rather than men, of techniques rather than mere wisdom, he believes that we would have had world government already if we had had "wise and determined" leadership; if only Roosevelt had not been shortsighted, he thinks the Soviet Union would have come into the United Nations without demanding a veto in the Security Council, and the U.S. Senate would have agreed.

If you agree with Esslinger's judgment on such practical issues, you may also agree with his prescription for the reform of political science.

DON K. PRICE

Scarsdale, New York

Charles Darwin: A Great Life in Brief. Ruth Moore. Knopf, New York, 1955. viii + 206 pp. $2.50.

Having said some rather harsh things about a previous book by Ruth Moore, *Man, Time, and Fossils,* I acknowledge an extra pleasure in saying some good words for this short life of Darwin. The author has used only the well-known sources for her sketch, but these she has absorbed with understanding. In a pleasant style, vivid and conversational, she sets the man, his life, his travels, his scientific endeavors, and his human weaknesses, as well as towering genius and ceaseless perseverance, all before us. It is a likeness familiar but none the less true for being familiar—quite unlike the warped and rather disagreeable figure portrayed in another book of the present year, *Apes, Angels, and Victorians,* by an author of greater erudition but seemingly no sympathy for his characters.

Ruth Moore at least admires the man of science and can approach him with some insight. She comes far closer to understanding his drives and motives, and to sensing his humanity, than the man of letters who sees only the neuroses and who cannot grasp how or why a biologist might spend 8 years in interminable studies of barnacles. William Irvine is absorbed in the hypochondriac whose motives seem mixed, who achieved in order to be well thought of by his fellow-scientists. Ruth Moore picks up no scalpel; she performs no dissection. But she sees the heart as well as the head, the eyes as well as the hands. Irvine cannot understand how a man of such mediocre gifts and such mixed motives can have reared so eternal a monument. Ruth Moore sees Darwin's flashes of insight, his dogged perseverance, and his utter devotion to the advancement of scientific truth. As the centenary of the *Origin of Species* draws near, and we appraise the still-growing impact of Darwin's thought and achievement, it seems to me that Ruth Moore is far nearer to the truth.

BENTLEY GLASS

Department of Biology, Johns Hopkins University

How to Know the Fresh-Water Algae. G. W. Prescott. Pictured-Key Nature Series. H. E. Jacques, Ed. Brown, Dubuque, Iowa, 1954. v + 211 pp. Illus. Spiral, $2; cloth, $2.75.

This little book is one of a series edited by H. E. Jacques and partakes of the character of the series. It will be a handy book for the general botanist who wishes to familiarize himself with the wonderful variety of small or microscopic plants to be found in ponds and streams, for the limnologist and the beginner in serious studies of fresh-water algae.

Although the title page indicates that the book deals with the common genera, in most groups it goes much further than the common ones and includes many reported only once, or little more. This is an advantage in that these will be brought to the attention of students,

a disadvantage in that it increases the length and complexity of the key.

The limitation of the diatoms almost to their exclusion is excessive and unrealistic. It is no more difficult to identify a fresh-water diatom to genus than a desmid, and no more difficult to illustrate the striking features. Furthermore, diatoms are much more important. Information on diatoms is much more eagerly sought than on other groups, and with little more effort the need could have been met. Quite enough space could have been saved by leaving out the rarities among the green algae. This is, however, the only regrettable shortage in the book.

A long key is a tremendous job to construct, and it looks as if Prescott has constructed a very good one, but only much use can expose hidden pitfalls. The key characters selected have quite rightly been simple ones, often accompanied by alternate or substitute characters. Since this is an artificial key, not one based on supposed phylogeny or taxonomic relationships, many short cuts are possible, which establish strange companionships but certainly help progress. A tabulation of the genera in taxonomic groupings finally straightens out the systematic order.

The illustrations of the many unicellular, colonial, and small filamentous genera are uniformly good, but those of the few of larger size are rather less so. Since space limitations permit few illustrations to a genus, the user may find it hard to convince himself, when he is dealing with such large genera as *Staurastrum*, that he has keyed his plant to the right ending. This is inevitable in a book of this scope; probably nowhere else will the user find so many illustrations in such small compass. The idea of illustrating the glossary is all right, but the combination of an illustrated glossary and the index is unfortunate and will make those pages less easy to use in either capacity.

WILLIAM RANDOLPH TAYLOR
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Careers and Opportunities in Science. Philip Pollack. Dutton, New York, 1954 (rev. ed. of *Careers in Science*). 252 pp. Illus. $3.75.

The publishers of this volume by Philip Pollack have done the author a distinct disservice by claiming too much. On the jacket they state that the volume covers "every detail which a young man or woman considering a career in science needs to know about his chosen field." Publishers and author would be well advised to sit in on a vocational guidance discussion to learn how far short the book falls of this extravagant claim.

In a series of 13 chapters the author darts deftly between and around an infinite number of exclamation marks, now describing a new discovery or invention, and here and there giving some solid factual information about the profession under consideration. Unless the student reader has already decided upon a specific career, the book leaves him unoriented and possibly tempted to dash off in all directions at once. For the person who knows what he wants to do, the guidance as to how to go about it is too diffuse and too incomplete.

It is unfortunate that we know so little about motivation. *Careers and Opportunities in Science* has been written in accordance with one theory of motivation that I am glad to see developed so completely. In my judgment, however, the theory has proved to be fallacious. The volume is not likely to interest an audience that is not already motivated toward a career in science, and the best guidance that is provided is presented in a fair bibliography and a useful appendix. Pollack is an excellent writer and has a great deal of scientific information at his command. It is unfortunate that the lucid snapshots of science that fill the pages of his book have so little to do with student guidance and are, besides, an unknown factor in providing motivation.

HOWARD A. MEYERHOFF
Scientific Manpower Commission, Washington, D.C.

Bird Navigation. G. V. T. Matthews. Cambridge Univ. Press, New York, 1955. vi + 140 pp. Illus $2.50.

Although this book has many fine features (for example, a historical summary, with 15 pages of references), it fails to achieve its purpose of explaining bird navigation. Active experimental programs on this problem are now to be found in a number of research centers. In combination, they represent a major research effort, and the current reports reflect scientific progress. With one exception, however, the investigators have not claimed to have the solution now. The exception is the author of this book.

Recent results show that birds released in strange territory may be observed to fly toward their distant homes. In 1951 Matthews offered a hypothesis based on the bird's interpretation of the position of the sun in the sky. In so doing, he attributed a precision of observation and measurement to the bird that exceeds any demonstrated sensitivity. The bird must see the sun *move* during the period immediately after release, must *extrapolate* the curve to get the highest point, and must compare the *time* and *elevation* of this *inferred* highest point with those of the *remembered* noon sun at home.

The evidence offered for sun navigation in birds is circumstantial, based largely on the fact that birds show poor orientation under clouds. But this observation, upon which all investigators agree, is open to interpretation in other ways. The book mentions two suggestions and argues against them without disposing of them.

The author of this book seems to abhor the unknown. One argument for sun navigation is that there is no other physical hypothesis currently in good standing. He cannot conceive of there being any physical basis still undiscovered. He dismisses dogmatically the question of whether extrasensory perception may be a factor

in bird navigation but, in doing so, shows a lack of knowledge of the evidence for ESP.

It is legitimate, of course, to choose sun navigation in birds as one's working hypothesis. However, the author appears to have been carried away by the idea, and he is too hasty in interpreting the facts as evidence for his hypothesis.

J. G. PRATT
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Psychoanalysis and the Education of the Child. Gerald H. J. Pearson. Norton, New York, 1954. x + 357 pp. $5.

Gerald Pearson has had a long interest in problems of children and their development. His book, *Emotional Disorders of Children,* and *Common Neuroses of Children and Adults* by Pearson and O. Spurgeon English, have represented for many years the two most comprehensive reference volumes that can be used by nonpsychoanalytically trained people in their quest for more understanding of children. In the present volume, Pearson's intention is to extend the hypotheses about child development that have been gained from deep psychoanalysis to problems faced by educators in developing their curriculums, methods of teaching, and objectives of education.

This is a courageous intention. There are two grave difficulties that stand in the way, and neither has been given any really novel treatment in the present volume. One is the fact that "universals" about normal processes of child development are not best studied by deep therapy of a few disturbed children. To one who has watched many children and observed the galaxy of motives that can instigate action, the didactic principles about normal development that Pearson presents in the first half of his book are too narrow and incomplete, as well as insufficiently proved, to be stated as established principles. I would prefer to have seen less reference to classical psychoanalytic writing and more to the sensitive studies of groups of children made by Anna Freud and others in recent years.

The other difficulty is, of course, placing material about inferred basic needs of the child into a setting in which planning for the child's education can be done. Here the author sets his hand to the plow firmly, but the extent of his success is not absolutely apparent. Pearson says that "The teacher needs intensive instruction about processes of development of the libido, the ego and the superego during the oral, anal-sadistic and phallic phases, in the latency period and through puberty and adolescence." Yet the material presented in this volume does not suggest broad lines along which planning of curriculums or methods of teaching should go as a consequence of the effect on the child of these stages of psychosexual development. To me, the extent to which such material can be used by teachers is far from clear. The applications made by the author are spotty and incomplete, but in fairness to him it should be said that he should not be expected to make the application singlehandedly.

Many examples of the difficulty could be cited, but perhaps two will illustrate sufficiently. The child's curiosity is named, correctly, as an important aid to the task of the teacher. But how is the teacher to evaluate and put to use the following information? "Curiosity is an oral character trait and may be marked by all the voracity of the original oral appetite. Reading as a substitute for eating is an oral-sadistic incorporation of alien objects. The linking of the ideational fields of looking and eating may be due to the child's having seen a younger sibling nursed. Reading may be correlated with intense inquisitiveness—a spasmlike, voracious looking which is a substitute for gluttony. Such oral uses of the ego represent a regression of visual perceptions to incorporation aims that were once connected with perceptions in general" (p. 139).

In this connection also, three types of result are cited for cases in which the period of sexual investigation comes to an end through too severe sexual repression: (i) the curiosity, as well as the sexuality, is inhibited, and the intelligence is narrowed for life; (ii) curiosity is strengthened by the repressed sexuality and returns as compulsive reasoning; and (iii) a rare reaction (ascribed by Freud to Leonardo da Vinci) in which the curiosity is reinforced by the sexual libido but all occupation with sexual themes is avoided.

Such material has great usefulness for clinical treatment of disturbed children but hardly aids in the understanding of curiosity in normal children who have avoided the severe sexual repression. Since the job of teachers is to put the child's curiosity to constructive use, rather than to treat clinically the inhibited curiosity of the rare child in whom normal development has been distorted, the question may be raised regarding the relevance of this in the educative process. Teachers need great energy, enthusiasm, and singleness of purpose to create stimulating opportunities for learning in their young charges. They need help from many other people, differently trained, in planning for a certain small percentage of children for whom current curriculums and methods are inadequate. But the contribution of psychoanalytic work to planning for the large groups of children has still not been made apparent.

PAULINE SNEDDEN SEARS
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Introduction to Theoretical Organic Chemistry. P. H. Hermans. Elsevier, New York–London, rev. ed., 1954. xii + 507 pp. Illus. $9.75.

The theoretical foundations of organic chemistry have become so labyrinthine, and their literature so voluminous, that it would be beyond the capabilities of any one author, and outside of the capacity of any one book, to cover the entire subject authoritatively and in detail. Accordingly a writer must choose between producing a specialized treatise in a narrower field, or a

rapid survey in which he hits only the high spots and hopes to encourage the reader to pursue individual topics further on his own.

Hermans has chosen the latter approach, attempting, as he states, ". . . to discuss a broad field in a simple and lucid manner without striving for completeness. No more than an elementary knowledge of physics and chemistry is required by the reader, and the use of mathematical formulae is reduced to a minimum." For an American reader, this probably means a good elementary course in descriptive organic chemistry, together with its usual prerequisites.

Roughly the first half of the book is concerned with the physical chemistry of organic molecules, the relationship between physical properties and electronic structure, the properties of acids and bases. Although the concepts involved have been discussed in greater detail elsewhere, they are here presented clearly and briefly.

The second half of the book deals with reaction mechanisms and probably covers a greater variety of organic reactions than any other current book. Although the treatment of all is necessarily sketchy and there are minor errors, attention is drawn to a number of reactions that must be unfamiliar to most readers. In fact the treatment of radical reactions is very up-to-date for a book at this level.

Hermans' book should be a useful textbook for at least part of a second-year course in advanced organic chemistry and would make welcome collateral reading in an elementary course, particularly for the interested student who wants to know the whys behind the confusion of facts he encounters in his first year. The translation is felicitous, but the book would gain by a better system of references. General reading is suggested at chapter ends and authors of specific works are mentioned, but the occasional journal references seem to have been chosen in a rather haphazard manner. The publisher's statement in the flyleaf that "this book could not be more up to date" is overly enthusiastic. It is reasonably complete through 1952. All in all, however, it should be a welcome addition to the libraries of both teachers and students in this active field.

CHEVES WALLING
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Culture and Human Fertility. A study of the relation of cultural conditions to fertility in non-industrial and transitional societies. Frank Lorimer. UNESCO, Paris, 1954 (Distributed by Columbia Univ. Press, New York). 514 pp. Paper, $4.50.

In recent decades there have been rapid advances in the concepts, methodology, and techniques of demographic research. Manifold and far-flung activities have led to proliferations of data. The generality of the conclusions of research has been limited, however, for there has been a geographical, a cultural, and an economic locus for the swift developments. Geographically it is Europe or Europeans overseas; culturally it is Western and Christian; economically it is industrial. The relevance of conclusions derived from the excellent data of Sweden in the 17th and 18th centuries to the present and future dynamics of population along the Yalu or around the shores of Victoria Nyanza is speculative. Moreover, to the general public, the world has been presented as a dichotomy of developed and underdeveloped areas, of industrial and preindustrial societies. There is a great controversy concerning whether that portion of the world's people defined as underdeveloped can develop economically more rapidly than they can increase demographically. In the meantime, research and the operational activities of technical assistance become so intermingled with humanitarianism and political expediency that many fail to distinguish their hopes and their visions from the facts.

Culture and Human Fertility has as its subtitle "A study of the relation of cultural conditions to fertility in non-industrial and transitional societies." It has an impressive sponsorship: The International Union for the Scientific Study of Population through its Committee on Population Problems of Countries in Process of Industrialization and the United Nations Educational, Scientific, and Cultural Organization. Resources-wise, facilities were very limited. No analytic survey of historical and contemporary materials was possible, and major field research could not be undertaken. Instead, there was a perusal of some segments of the materials in their vastness and diversity that was followed by the formulation of a basic hypothesis and then the verification, elaboration, and modification of the hypothesis through further perusal of materials for other cultures. All this was carried out as a one-man task in a limited period of time. It is within this context that the work must be evaluated.

The first half of the book is "General theory" by Lorimer. The initial concern is "Capacity for procreation and levels of natality," an attempt to assess from observed levels of very high fertility and some hypothetical models what the childbearing of women would be by the end of the reproductive period under maximum reproductive and physical conditions, neither precisely defined. Lorimer then considers kinship as "the most pervasive fabric of the social structure of many primitive and agrarian societies." It is in the kinship system that he finds the key to the relationship of culture to fertility. A review of the evidence, mainly from sub-Saharan Africa, leads to the theory that "Corporate unilateral kinship groups and the related emphasis on mother rights or father rights in social organization tend to generate strong motivations for high fertility." This theory forms the organizational motif for further chapters. In chapter 3, "Environment, culture, and fertility," the theory is extended to cover the superiority of the lineage kinship structure in intertribal conflict. Arguments are mainly from the Turkic and Mongolian pastoral societies of Central Asia, but some attention is given to the marginal societies of the Pacific. In chapter 4, "Culturally uncontrolled trends in fertility," the argument encompasses the physiological

and cultural factors tending to induce low fertility under conditions of cultural shock. Illustrations here are drawn from central Africa, Micronesia, and the American Indians. Final chapters concern "Cultural conditions and fertility in stable agrarian civilization" and "The relation of cultural conditions to the demographic transition."

Four studies are included as supporting documentation, but only the first three find any major use in the analysis. The first, "A demographic field study in Ashanti," by Meyer Fortes, was part of a sociological, geographic, and economic study of the Gold Coast carried out by the sociological department of the West African Institute in 1945. The second, K. A. Busia's "Some aspects of the relation of social conditions to human fertility in the Gold Coast," is a brief report on an exploratory study. The third, "Report on fertility surveys in Buganda and Buhaya, 1952," by Audrey I. Richards and Priscilla Reining, is a preliminary report. The fourth, "The Brazilian birth rate: its economic and social factors," by Giorgio Mortara, places in concise form in English much of Mortara's work that has hitherto been available only in Portuguese.

Culture and Human Fertility is stimulating much discussion among population students and anthropologists. It is to be hoped that it also stimulates both further theoretical work and controlled and meaningful field studies in a variety of social, economic, and cultural situations.

IRENE B. TAEUBER
Office of Population Research, Princeton University

The Story of Medicine. Kenneth Walker. Oxford Univ. Press, New York, 1955. 343 pp. Illus. + plates. $6.

Kenneth Walker's *The Story of Medicine* is a breezy, facile, but unfortunately neither precise nor always correct, recitation of the story of medicine. Thus, for example, Noguchi is given as the "partner" of Ehrlich in the discovery of salvarsan. In effect, it was another Japanese scientist, Sakahiro Hata, and he was a coworker and never a partner (p. 252). Théophile de Bourdeu is consistently given as de Borden (p. 277). Moritz Schiff was a German, not a Swiss, and he died in 1896, not in 1890. It was Father Hell and not Prof. Hehl (p. 307) from whom Mesmer obtained a number of magnets. Paracelsus was not "the only child of a nobleman of the house of the Bombasts" (p. 121). Freud did not visit Paris "before starting to practise," nor did he after that visit decide "henceforth to devote himself entirely to the treatment of nervous disorders" (p. 314). It was not at Charcot's clinic that he first encountered Breuer. Philippe Pinel was not physician to the Biûtre Prison [*sic*]; he was first at the Bicêtre Hospital, and then at the Salpêtrière. And so on, and so on!

But even more objectionable are such easy and totally erroneous generalizations as "although Charcot was a brilliant investigator he was a poor clinician" (p. 313). "He did little to advance medical practice" (p. 314). "Ancient Jewish medicine was very primitive, and except for the excellent preventive measures laid down by the Mosaic Law it is of little interest to us" (p. 34). "John Hunter was the youngest of a family of eleven and this desire to excel everybody else was very firmly implanted in him" (p. 167). That is probably why, when he came up to London in 1748 at 20 years of age, he was "a raw, uncouth Scotch lad, fonder of taverns and theater galleries than of book learning" (Garrison).

All this is a great pity, and I wish it were otherwise. For Walker has written his work with enthusiasm and professes to have "quite unexpectedly" snatched both enjoyment and profit out of the task. Perhaps the answer to it all lies in the following lines taken (out of context) from his preface: "Looking back on the work of the last six months, as I now do from the pinnacle of preface writing, I am no longer surprised at what has happened."

IAGO GALDSTON
New York Academy of Medicine

Highway to the North. Frank Illingworth. Philosophical Library, New York, 1955. xvi + 293 pp. Illus. + plates. $7.50.

This is the record of a journey north on the Alaskan Highway to Fairbanks and from there to Kotzebue by air that was made by an Englishman in 1952. For me, the book produces a kind of nostalgia. Even names such as Watson Lake and Burwash Landing revive vivid memories of the construction of the Alaskan Highway in 1942. In addition, the names of old friends such as Jimmy Joe and John Cross pop up in every chapter. Anyone who knows and loves the North will find himself on familiar trails while he is reading this book. It is a simple narrative of people and places told with obvious sincerity and complete accuracy. It has no real beginning or ending, it does not tend to prove or disprove anything, and it has no ax to grind. It is a sentimental journey to the North, pleasing in its simplicity and British understatement.

Illingworth is obviously a restless fellow who likes people and particularly people in odd corners of the earth. He is sympathetic but not sentimental about the natives and certainly has tried hard to understand them. The sentimental parts are reserved for the old-timers, the relicts of the gold rush. I suppose any of us who lived for years in the Arctic must squirm a bit at all those same old references to Robert Service, his poems, and the timeworn tales of the Klondike, but this is the Arctic that the outsider knows most about, and the successful travel writer must make his bow to them in any tale of Alaska and Yukon territory. In addition, Illingworth's preoccupation with the period of the gold rush reminds you that every country must have its folklore. Despite the huge trucks along the Alaskan Highway, the military air bases, and modern age of flight, the author again and again reminds us that it is the gold rush that has put its peculiar stamp on the Yukon.

Illingworth gives a clear and honest picture of the northwest Arctic in 1952. It should be of great interest to anyone who plans a trip on the Alaskan Highway for a first visit to the Yukon. For old Alaskans who want to know what has happened since the highway and air force have come to this part of the world, it is almost as good as a gab session with old friends in one of the road houses. It is good to read and review a travel book without having to pick out and correct errors of fact. The author obviously took many notes along his way and carefully stuck to them in his writing.

FROELICH RAINEY
University Museum, University of Pennsylvania

Poissons. IV. Téléostéens Acanthoptérygiens (Première Partie). (Résultats Scientifiques, Expédition Océanographique Belge dans les Eaux Côtières Africaines de l' Atlantique Sud, 1948–1949). Max Poll. Institut Royal des Sciences Naturelles de Belgique, Brussels, 1954. 390 pp. Illus. + plates. Paper, F. 675.

In this first part of the report on the acanthopterygian fishes of the expedition, 97 species are discussed, of which 86 are Perciformes, principally Sciaenidae and Sparidae. This part is strictly systematic; general comments on the fish fauna are confined to the introductory pages, and a tabulation of bathymetric ranges of the species discussed concludes the report.

JOEL W. HEDGPETH
Scripps Institution of Oceanography

Africa Today. C. Grove Haines, Ed. Johns Hopkins Press, Baltimore, Md., 1955. xvi + 510 pp. Illus. $6.

Africa Today is one of a small group of recent books that should cause American readers to cease thinking of Africa as an appendage of Europe and begin to regard it as a continent in its own right. It is timely and up to date. It covers most of the important problems of the continent. Its near score of authors speak with authority, some, like Philip Mitchell, from long years of intimate experience with the African scene. The volume is the product of a conference on contemporary Africa, sponsored in Washington during August 1954, by the Johns Hopkins University School of Advanced International Studies. For the body of the volume C. Grove Haines, director of the school and organizer of the conference, has assembled the principal talks given before that conference, together with commentaries on those talks. Haines is to be congratulated on placing such a wealth of material so expeditiously before students of African problems.

After a foreword by the editor and an introduction by Lord Hailey, the body of the work is divided into six parts. "The position of Africa in world affairs" contains an article presenting a defense of colonialism in Africa, one dealing with the importance of the anthropologic approach to administration, and one on the continent's strategic importance. "The heritage of Africa" deals with the African's dependence upon his tribal organization, the impact of Christianity and Islamism on African culture, together with the impact upon that culture of Europeans in general and Western education in particular. "Elements of political and social upheaval" contains one article that divides politically all sub-Saharan Africa into integrationist, crossroads, and segregationist groups; another presents a historical explanation of *apartheid*; still another traces the importance of trade unions to emergent political parties; and a final one deals with the communist threat to Africa, which is concluded to be real, not merely potential. "Recent developments in the African dependencies" deals with the problems of independence as exemplified by Nigeria and the Gold Coast, the problems of French and Belgian Africa, and finally the impact of the United Nations on Africa, which is presented as a mixed blessing at best, from the viewpoint of possible European-African accord. "The economic status and future possibilities of Africa" presents a moderate picture, stressing the prevalence of both the drouth and tsetse fly as well as great mineral wealth. "The United States and Africa" is presented from both the American and African view. The work concludes with an appendix on the Mau Mau by Mitchell. As can be seen, the scope of the book is large.

Because of the scope and timeliness of the book, it must be recommended to serious students of African problems. It could be recommended with greater enthusiasm were it not for its several faults. Most of these faults appear to arise from the failure of the editor to exercise his prerogative with a firm hand.

Perhaps the most serious omission in the book is in the number of maps and illustrations. A happy exception to this generalization is Edwin S. Munger's "Geography of sub-Saharan race relations." Elsewhere the lack of maps hinders an easy understanding of the text, which is replete with references to African place-names. At least a folded map or a map printed on the end papers is seriously needed. Several maps showing the distribution of the various items discussed in the text would have been even better. Illustrations of scenes that are not familiar to American readers would have added to the work.

Had an editorial decision been made to eliminate the commentaries on the talks, little of worth would have been lost and the volume would have been improved. Prepared comments are designed to assure a paper or talk adequate consideration from the floor of a meeting. They may or may not do this, a fact that has been illustrated many times at meetings of the Association of American Geographers where a similar technique has been used during recent years. But, as this volume demonstrates, such comments add little when the talks or papers are available in printed form.

A less sparing use of the editorial pencil on the articles themselves would have improved them. No one will challenge the expertness of the authors, but they have spoken with a varying degree of facility. In my opinion three articles stand out in their mode of presentation. They give the complexity of Africa with

clarity but not oversimplification. They are Elizabeth Colson's discussion of tribal relationships, Cornelias W. de Kiewiet's historical explanation of *apartheid*, and Kofi A. Busia's account of what happens when nations shift from colonial status to self-government. But many of the articles fail to reach the level of these presentations. As a result of this unevenness of presentation, coupled with an individuality among authors in handling material and the lack of any conclusion or summary, this book as a whole lacks unity and coherence. As an example of cooperative research, it leaves much to be desired. Nonetheless, because of its scope and its timeliness, it is recommended to those who wish to understand Africa better.

H. THOMPSON STRAW
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Books Reviewed in SCIENCE

2 December

An Outline of Atomic Physics, O. H. Blackwood, T. H. Osgood, A. E. Ruark (Wiley; Chapman & Hall). Reviewed by R. M. Steffen.

Bergsonian Philosophy and Thomism, J. Maritain (Philosophical Library). Reviewed by D. Bidney.

Annual Reviews of Plant Physiology, D. I. Arnon, Ed. (Annual Reviews). Reviewed by P. Saltman.

Polarographic Techniques, L. Meites (Interscience). Reviewed by H. A. Saroff.

Histologische Geschwulstdiagnostik, A. V. Albertini (Thieme). Reviewed by S. Peller.

Perinatal Mortality in New York City: Responsible Factors, S. G. Kohl (Harvard Univ. Press). Reviewed by H. Bakwin.

Theoretical Structural Metallurgy, A. H. Cottrell (St. Martin's Press). Reviewed by P. Haasen.

The Biology of a Marine Copepod Calanus finmarchicus (Gunnerus), S. M. Marshall and A. P. Orr (Oliver & Boyd). Reviewed by J. W. Hedgpeth.

Radiobiology Symposium, 1954, Z. M. Bacq and P. Alexander, Eds. (Academic Press; Butterworths). Reviewed by C. L. Dunham.

9 December

Symposium on Atherosclerosis (National Acad. of Sciences–National Research Council). Reviewed by D. Barr.

The Story of FAO, G. Hambidge (Van Nostrand). Reviewed by N. Clark.

Chemical Engineering Cost Estimation, R. S. Aries and R. D. Newton (McGraw-Hill). Reviewed by J. M. DallaValle.

Inorganic Reactions and Structure, E. S. Gould (Holt). Reviewed by C. R. Naeser.

A Study of the Brain, H. S. Rubinstein (Grune and Stratton). Reviewed by D. H. Barron.

The Origin of Vertebrates, N. J. Berrill (Oxford Univ. Press). Reviewed by G. G. Simpson.

The Quantitative Analysis of Drugs, D. C. Garratt (Philosophical Library). Reviewed by R. P. Walton.

Vascular Plants of Illinois, G. N. Jones, G. D. Fuller *et al.* (Univ. of Illinois Press and Illinois State Museum). Reviewed by L. Constance.

16 December

Receptors and Sensory Perception, R. Granit (Yale Univ. Press). Reviewed by S. W. Kuffler.

Bau der Südamerikanischen Kordillere, H. Gerth (Borntraeger, Berlin). Reviewed by A. A. Meyerhoff.

Enfermedades Infecciosas y Parasitarias, J. Ink (Lopez y Etchegoyen, Buenos Aires). Reviewed by B. Monis.

Causalités et Accidents de la Découverte Scientifique, R. Taton (Masson). Reviewed by P. Le Corbeiller.

Principles of Nuclear Reactor Engineering, S. Glasstone (Van Nostrand). Reviewed by S. McLain.

Scientific Method in Psychology, C. W. Brown and E. E. Ghiselli (McGraw-Hill). Reviewed by D. J. Lewis.

Electrochemistry in Biology and Medicine, T. Shedlovsky, Ed. (Wiley; Chapman & Hall). Reviewed by R. C. Warner.

The Roger Adams Symposium (Wiley; Chapman & Hall). Reviewed by H. Gilman.

Antimetabolites and Cancer, C. P. Rhoads, Ed. (AAAS). Reviewed by J. H. Edgcomb.

23 December

Engineering Metallurgy, L. F. Mondolfo and O. Zmeskal (McGraw-Hill). Reviewed by J. L. Scott.

Basic Processes of Gaseous Electronics, L. B. Loeb (Univ. of Calif. Press). Reviewed by W. B. Nottingham.

Radio Astronomy, J. L. Pawsey and R. N. Bracewell (Oxford Univ. Press). Reviewed by B. J. Bok.

Nuclear and Radiochemistry, G. Friedlander and J. W. Kennedy (Wiley). Reviewed by M. D. Kamen.

The Negro in Science, J. H. Taylor, Ed. (Morgan State College Press). Reviewed by D. Wolfle.

Metals Reference Book, C. J. Smithells (Interscience; Butterworths). Reviewed by T. B. Massalski.

Theory of Functions of a Real Variable, I. P. Natanson (Ungar). Reviewed by A. Rosenthal.

30 December

The Biology of the Amphibia, G. K. Noble (Dover). Reviewed by A. H. Wright.

Actions of Radiations on Living Cells, D. E. Lea (Cambridge Univ. Press).

Catalogue of the Type Specimens of Microlepidoptera in the British Museum (Natural History) Described by Edward Meyrick, J. F. G. Clarke (British Museum of Natural History). Reviewed by F. R. Fosberg.

Classical Electricity and Magnetism, W. K. Panofsky and M. Phillips (Addison-Wesley). Reviewed by R. H. Whitmer.

Experimental Design and Its Statistical Basis, D. J. Finney (Univ. of Chicago Press). Reviewed by D. Mainland.

The World We Live In, L. Barnett and editorial staff of *Life* (Time, Inc.).

Introductory Nuclear Physics, D. Halliday (Wiley; Chapman & Hall). Reviewed by W. B. Fretter.

Radioisotopes in Biology and Agriculture: Principles and Practice, C. L. Comar (McGraw-Hill). Reviewed by S. Udenfriend.

New Books

Atomic Physics. An atomic description of physical phenomena. Gaylord P. Harnwell and William E. Stephens. McGraw-Hill, New York, 1955. 401 pp. $8.

Traité de la Connaissance. Louis Rougier. Gauthier-Villars, Paris, 1955. 450 pp. $6.48.

Technical Publications. Their purpose, preparation, and production. C. Baker. Wiley, New York, 1955. $6.

Jet Engine Manual. E. Mangham and A. Peace. Philosophical Library, New York 16, 1955. 133 pp. $3.75.

Environmental Hygiene. vol. II of *Preventive Medicine in World War II.* Ebbe Curtis Hoff., Ed. Historical Unit, Army Medical Service, Washington, 1955 (Order from Supt. of Documents, GPO, Washington 25). 404 pp. $3.50.

Hydrogen Peroxide. Walter C. Schumb, Charles N. Satterfield, and Ralph L. Wentworth. Reinhold, New York; Chapman & Hall, London, 1955. 759 pp. $16.50.

International Pharmacopoeia. vol. II. World Health Organization, Geneva, 1955. 350 pp. $6.75.

Astrophysical Quantities. C. W. Allen. Athlone Press, London, 1955, (Distributed in U.S. by John de Graff, Inc., New York 10). 263 pp. $10.

Ultrasonic Engineering with Particular Reference to High Power Applications. Alan E. Crawford. Academic Press, New York; Butterworths, London, 1955. 344 pp. $8.

Introduction to Virology. Gilbert Dalldorf. Thomas, Springfield, Ill., 1955. 102 pp. $3.50.

Bibliography and Index of Geology Exclusive of North America. vol. 19. Marie Siegrist *et al.* Geological Soc. of America, New York, 1955. 689 pp.

Research Films in Biology, Anthropology, Psychology, and Medicine. Anthony R. Michaelis. Academic Press, New York, 1955. 490 pp. $10.

Group Processes. Transactions of the first conference on group processes, 26–30 September 1954, Ithaca, N.Y. Berthram Schaffner, Ed. Josiah Macy, Jr. Foundation, New York, 1955. 334 pp. $5.50.

Small-Angle Scattering of X-Rays. André Guinier and Gerard Fournet. Trans by Christopher B. Walker. Wiley, New York; Chapman & Hall, London, 1955. 268 pp. $7.50.

Introduction to Modern Physics. F. K. Richtmyer, E. H. Kennard and T. Lauritsen. McGraw-Hill, New York, ed. 5, 1955. 666 pp. $8.50.

The Atomic Nucleus. Robley D. Evans. McGraw-Hill, New York, 1955. 972 pp. $14.50.

Organic Insecticides. Their chemistry and mode of action. Robert L. Metcalf. Interscience, New York–London, 1955. 392 pp. $8.50.

Bibliography of Monolingual Scientific and Technical Glossaries. vol. I, *National Standards.* Eugen Wüster. UNESCO, Paris, 1955 (Order from Columbia Univ. Press, New York 27). 219 pp. $2.50.

The Value of Judgment. W. D. Lamont. Philosophical Library, New York, 1955. 335 pp. $6.

The World of Bees. Gilbert Nixon. Philosophical Library, New York, 1955. 214 pp. $4.75.

Gas Turbines and Jet Propulsion. G. Geoffrey Smith; revised and enlarged by F. C. Sheffield. Iliffe, London and Philosophical Library, New York, ed. 6, 1955. 412 pp. $15.

European Architecture in the Twentieth Century. vol. 2. pt. 3, *The Era of Functionalism. 1924–1933.* Arnold Whittick. Philosophical Library, New York 16, 1955. 271 pp. $10.

Constructional Steelwork. Oscar Faber. Philosophical Library, New York, 1955. 367 pp. $12.

Transistors and Other Crystal Valves. T. R. Scott. MacDonald & Evans, London; Essential Books, Fairlawn, N.J., 1955. 258 pp. $7.20.

Drying and Dehydration of Foods. Harry W. von Loesecke. Reinhold, New York; Chapman & Hall, London, 1955. 300 pp. $7.50.

Water. *The Yearbook of Agriculture, 1955.* U. S. Dept. of Agriculture, Washington, 1955 (Order from Supt. of Documents, GPO, Washington 25). 751 pp. $2.

A Course in Modern Techniques of Organic Chemistry. R. P. Linstead, J. A. Elvidge, and Margaret Whalley. Academic Press, New York; Butterworths, London, 1955. 190 pp. $5.

Structure of the Ego. An anatomic and physiologic interpretation of the psyche based on the psychology of Otto Rank. Lovell Langstroth. Stanford Univ. Press, Stanford, Calif; Oxford Univ. Press, London, 1955. 149 pp. $4.

Instrument Engineering. vol. III, *Applications of the Instrument Engineering Method*; pt. 1, *Measurement Systems.* Charles Stark Draper, Walter McKay, and Sidney Lees. McGraw-Hill, New York, 1955. 879 pp. $17.50.

Vitamins and Hormones. vol. XIII. *Advances in Research and Applications.* Robert S. Harris, G. F. Marrian, and Kenneth V. Thimann, Eds. Academic Press, New York, 1955. 382 pp. $9.

Theory of Games as a Tool for the Moral Philosopher. An inaugural lecture delivered in Cambridge on 2 December 1954. R. B. Braithwaite. Cambridge Univ. Press, New York, 1955. 75 pp. $1.25.

The Odyssey of a Psychologist. Pioneering experiences in special education, clinical psychology, and mental hygiene with a comprehensive bibliography of the author's publications. J. E. Wallace Wallin. The Author, 311 Highland Ave., Lyndalia, Wilmington 4, Del., 1955. 243 pp. Paper, $2.50 (prepaid).

How to Reduce Surely and Safely. Herbert Pollack with Arthur D. Morse. McGraw-Hill, New York, 1955. 157 pp. $2.95.

Development and Differentiation—Biochemistry, Physiology, Methodology. Experimental Cell Research, Supplement 3. Presented to John Runnström; arranged by T. Caspersson *et al.* Academic Press, New York, 1955. 416 pp. Paper, $8.

Almanac and Weather Forecaster. Eric Sloane. Duell, Sloan and Pearce, New York; Little, Brown, Boston, 1955. 169 pp. $3.50.

Classics of Biology. August Pi Suñer; trans. by Charles M. Stern. Philosophical Library, New York, 1955. 337 pp. $7.50.

The Development of Academic Freedom in the United States. Richard Hofstadter and Walter Metzger. Columbia Univ. Press, New York, 1955. 527 pp. $5.50.

200 Miles Up. The conquest of the upper air. J. Gordon Vaeth. Ronald Press, New York, ed. 2, 1955. 261 pp. $5.

Smithsonian Institution, Annual Report of the Board of Regents. Publ. 4190. Government Printing Office, Washington, 1955. 455 pp.

Klinische Elektrokardiographie. Max Holzmann. Thieme, Stuttgart, Germany, 1955. 687 pp. $19.05.

Principles and Applications of Physics. Otto Blüh in collaboration with Joseph Denison Elder. Interscience, New York, 1955. 866 pp. $7.

Medical Research: A Midcentury Survey. vol. I, *American Medical Research in Principle and Practice*; 765 pp. vol. II, *Unsolved Clinical Problems in Biological Perspective*; 740 pp. (Little, Brown, for the American Foundation, New York 17), Boston, 1955. 2 vols., $15.

Niels Bohr and the Development of Physics. Essays dedicated to Niels Bohr on the occasion of his seventieth birthday. W. Pauli, Ed. McGraw-Hill, New York; Pergamon, London, 1955. 195 pp. $4.50.

Academic Freedom in Our Time. Robert M. MacIver. Columbia Univ. Press, New York, 1955. 329 pp. $4.

Boltzmann's Distribution Law. E. A. Guggenheim. North-Holland, Amsterdam; Interscience, New York, 1955. 61 pp. $1.50.

Alternatives to the H-Bomb. A symposium organized by *The New Leader*. Anatole Shub, Ed. Beacon Press, Boston, 1955. 124 pp. Paper $1.

Research Frontiers in Politics and Government. Brookings lectures, 1955. Stephen K. Bailey, Herbert A. Simon, Robert A. Dahl, Richard C. Snyder, Alfred de Grazia, Malcolm Moos, Paul T. David, and David B. Truman. Brookings Institution, Washington, 1955. 240 pp. $2.75.

Reflections of a Physicist. P. W. Bridgman. Philosophical Library, New York, ed. 2, 1955. 576 pp. $6.

Electronic Transformers and Circuits. Reuben Lee. Wiley, New York, and Chapman & Hall, London, ed 2, 1955. 360 pp. $7.50.

Molecular Beams. K. F. Smith. Methuen, London; Wiley, New York, 1955 (ed. 2 of *Molecular Beams*, Ronald Fraser, 1937). 133 pp. $2.

Nuclear Radiation Detectors. J. Sharpe. Methuen, London; Wiley, New York, 1955. 179 pp.

Physical Techniques in Biological Research. vol. 1, *Optical Techniques*. Gerald Oster and Arthur W. Pollister, Eds. Academic Press, New York, 1955. 564 pp. $13.50.

Administrative Medicine. Transactions of the third conference, 6–8 October 1954, Princeton, N.J. George S. Stevenson, Ed. Josiah Macy, Jr. Foundation, New York, 1955. 172 pp. $3.

An Elementary Textbook of Psychoanalysis. Charles Brenner. International Universities Press, New York, 1955. 219 pp. $4.

Proceedings of the Conference on Latin-American Geology. Held 29–30 March 1954; cosponsored by the Department of Geology and the Institute of Latin-American Studies, University of Texas. Fred M. Bullard, Ed. Univ. of Texas, Austin, 1955. 99 pp.

Basic Mathematics for Science and Engineering. Paul G. Andres, Hugh J. Miser, and Haim Reingold. Wiley, New York; Chapman & Hall, London, 1955 (A revision of *Basic Mathematics for Engineers*, 1944). 846 pp. $6.75.

Microbiology. Florene C. Kelly and K. Eileen Hite. Appleton-Century-Crofts, New York, ed. 2., 1955. 615 pp.

Treatise on Invertebrate Paleontology. part V. Graptolithina with sections on Enteropneusta and Pterobranchia. Raymond C. Moore, Ed. Geological Soc. of America, New York, and Univ. of Kansas Press, Lawrence, 1955. 101 pp. $3.

Meetings

February

13–17. American Soc. of Civil Engineers, Dallas, Tex. (ASCE, 33 W. 39 St., New York 18.)

16–17. National Conf. on Transistor Circuits, 3rd, Philadelphia, Pa. (J. D. Chapline, Remington Rand, Inc., 2300 W. Allegheny Ave., Philadelphia 29.)

17–18. National Soc. of Professional Engineers, annual spring, Washington, D.C. (K. E. Trombley, NSPE, 1121 15 St., NW, Washington 5.)

19–23. American Inst. of Mining and Metallurgical Engineers, New York, N.Y. (E. O. Kirkendall, AIME, 29 W. 39 St., New York 18.)

19–23. Soc. of Economic Geologists, New York, N.Y. (O. N. Rove, Union Carbide and Carbon Corp., 30 E. 42 St., New York 17.)

20–22. American Educational Research Assoc., annual, Atlantic City, N.J. (F. W. Hubbard, AERA, 1201 16 St., NW, Washington 6.)

23–25. National Soc. of College Teachers of Education, Chicago, Ill. (C. A. Eggertsen, School of Education, Univ. of Michigan, Ann Arbor.)

24–25. American Physical Soc., Houston, Tex. (K. K. Darrow, APS, Columbia Univ., New York 27.)

26–29. American Inst. of Chemical Engineers, Los Angeles, Calif. (F. J. Van Antwerpen, AIChE, 25 W. 45 St., New York 36.)

28–29. Scintillation Counter Symposium, 5th, Washington, D.C. (G. A. Morton, RCA Laboratories, Princeton, N.J.)

March

9–10. Midwest Conf. on Theoretical Physics, Iowa City, Iowa. (J. M. Jauch, Dept. of Physics, State Univ. of Iowa, Iowa City.)

12–16. National Assoc. of Corrosion Engineers, 12th annual, New York, N.Y. (Secretary, NACE, Southern Standard Bldg., Houston 2, Tex.)

14–17. National Science Teachers Assoc., Washington, D.C. (R. H. Carleton, NSTA, 1201 16 St., NW, Washington 6.)

15–16. Food Physics Symposium, 1st international, San Antonio, Tex. (C. W. Smith, Southwest Research Inst., San Antonio.)

15–17. American Orthopsychiatric Assoc., 33rd annual, New York, N.Y. (M. F. Langer, AOA, 1790 Broadway, New York 19.)

15–17. American Physical Soc., Pittsburgh, Pa. (K. K. Darrow, APS, Columbia Univ., New York 27.)

15–17. Kappa Delta Pi, annual, Stillwater, Okla. (E. I. F. Williams, 238 E. Perry St., Tiffin, Ohio.)

16–18. International Assoc. for Dental Research, St. Louis, Mo. (D. Y. Burrill, 129 E. Broadway, Louisville 2, Ky.)

18–24. American Soc. of Photogrammetry, annual, joint meeting with American Cong. on Surveying and Mapping, Washington, D.C. (ACSM–ASP, Box 470, Washington 4.)

19–21. Div. of Fluid Dynamics, American Physical Soc., Pasadena, Calif. (F. N. Frenkiel, Applied Physics Lab., Johns Hopkins Univ., 8621 Georgia Ave., Silver Spring, Md.)

19–22. American Acad. of General Practice Scientific Assembly, 8th annual, Washington, D.C. (AAGP, Broadway at 34th, Kansas City 11, Mo.)

19–22. Inst. of Radio Engineers National Convention, New York, N.Y. (E. K. Gamett, IRE, 1 E. 79 St., New York 21.)

19–23. American Soc. of Tool Engineers, Chicago, Ill. (H. C. Miller, Armour Research Foundation, 35 W. 33 St., Chicago 16.)

21–22. National Health Forum, New York, N.Y. (T. G. Klumpp, National Health Council, 1790 Broadway, New York 19.)

21–23. American Power Conf., 18th annual, Chicago, Ill. (R. A. Budenholzer, Illinois Inst. of Technology, Chicago 16.)

21–24. American Astronomical Soc., Columbus, Ohio. (J. A. Hynek, McMillin Observatory, Ohio State Univ., Columbus 10.)

23–24. Eastern Psychological Assoc., Atlantic City, N.J. (G. G. Lane, Univ. of Delaware, Newark.)

24–25. American Psychosomatic Soc., 13th annual, Boston, Mass. (T. Lidz, APS, 551 Madison Ave., New York 22.)

24–31. Perspectives in Marine Biology, La Jolla, Calif. A. A. Buzzati-Traverso, Scripps Institution of Oceanography, La Jolla.)

25–28. American Assoc. of Dental Schools, annual, St. Louis, Mo. (M. W. McCrea, 42 S. Greene St., Baltimore 1, Md.)

25–29. American College Personnel Assoc., Washington, D.C. (Miss C. M. Northrup, Univ. of Denver, Denver, Colo.)

28–3. Colloquium on Frontiers in Physical Optics, Boston, Mass. (S. S. Ballard, Visibility Lab., Scripps Institution of Oceanography, San Diego 52, Calif.)

29–31. Pennsylvania Acad. of Science, Indiana, Pa. (K. Dearolf, Public Museum and Art Gallery, Reading, Pa.)

29–31. Southern Soc. for Philosophy and Psychology, Ashville, N.C. (J. E. Moore, Georgia Inst. of Technology, Atlanta, Ga.)

29–31. Symposium on Fundamental Cancer Research, 10th annual, Houston, Tex. (G. Taylor, Univ. of Texas Postgraduate School of Medicine, Houston 25.)

30–31. Alabama Acad. of Science, annual, Montevallo. (H. A. McCullough, Howard College, Birmingham, Ala.)

April

2–5. Assoc. of American Geographers, annual, Montreal, Canada. (B. W. Adkinson, Library of Congress, Washington 25.)

2–7. Symposium on Crystallography, Madrid, Spain. (M. Abbad, Serrano 118, Madrid.)

3. Microcirculatory Conf., 3rd, Milwaukee, Wis. (G. P. Fulton, Dept. of Biology, Boston Univ., 675 Commonwealth Ave., Boston 15, Mass.)

3–9. International Symposium on Macromolecular Chemistry. Rehovoth, Jerusalem, and Haifa, Israel. (A. Katchalsky, Weizmann Inst. of Science, Rehovoth.)

4–6. American Assoc. of Anatomists, annual, Milwaukee, Wis. (N. L. Hoerr, 2109 Adelbert Rd., Cleveland 6, Ohio.)

4–7. International Cong. of Medical Radiography, 2nd, Paris, France. (The Congress, Via Nazionale 200, Rome, Italy.)

5–6. Conf. on Magnetic Amplifiers, Syracuse, N.Y. (C. A. Priest, 314 Hurlburt Rd., Syracuse 3.)